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SAFE SECTION

INFORMATION REQUEST NUMBER 23

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LAI 0291

Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites in Missouri

Fiscal Year 1987
Annual Report

MISSOURI
DEPARTMENT OF NATURAL RESOURCES
Division of Environmental Quality

Confirmed Abandoned - Uncontrolled Waste Disposal sites in Missouri, Fiscal Year 1987 Report.

WESTLAKE LANDFILL

Classification: Class III, Priority 14

Site Name: Westlake Landfill

Address: Bridgeton, MO 63042. Between Old Rock Hill Road and New Rock Hill Road east of Earth City, St. Louis County
T 46 N, R 5 E, St. Charles Quadrangle

Waste Type: radionuclides

Quantity: 7000 tons of low level uranium ore wastes

Site Description:

The site is part of an active landfill on the Missouri River floodplain in St. Louis County..

Present Owner: Westlake Landfill, Inc.,
Bridgeton, MO 63042

Environmental Problems Related to Site:

The site is an active permitted landfill which in the past accepted 7000 tons of low level uranium ore wastes. Excavation at the site in the past reached the same depth as the groundwater. There is potential for contamination of groundwater and the Missouri River which is less than one mile away, directly west of the site.

Remedial Actions at Site:

The site was surveyed prior to expansion in order to separate the demolition fill area from the area identified as containing hazardous materials.

The Missouri Department of Natural Resources is the lead agency for this site.

Area of Concern Related to Site:

The average natural ground elevation is 435 to 440 feet with groundwater at a shallow depth. The alluvium underlying the river is one of the most important aquifers in the state. Consequently, if contamination is occuring from the landfill, it is threatening a vital aquifer resource.

General Geologic and Hydrologic Setting:

LOCATION: Longitude 90 26' 45"; latitude 38 46' 15", St. Charles Quadrangle.

The landfill has been in existence for more than twenty years. For most of that time period, landfilling has occurred on the Missouri River floodplain. Landfilling also has taken place in a limestone quarry adjoining the floodplain landfill. The quarry is in the St. Louis Limestone which is present along the eastern slopes of the Missouri River floodplain.

The early portion of the landfill operation included excavation and filling below the floodplain and into the groundwater of the Missouri River aquifer. Subsequent landfill operations generally were confined to filling above the floodplain surface and also in the adjoining limestone quarry. Except where operational procedures cause outbreaks of leachate to occur in the quarry or runoff water to drain into the quarry, there was no evidence of significant amounts of groundwater from the alluvial aquifer entering the limestone. For the most part, the recharge, quite limited to begin with, would be from the bedrock adjoining the alluvium into the Missouri River aquifer rather than the aquifer recharging the surrounding bedrock. Near the bedrock quarry pit, however, the potential exists for draining some alluvial water into this sump. Apparently, the pit is dewatered on a continuous basis with the water pumped to discharge in the alluvial setting. Groundwater monitoring indicates general movement of the alluvial groundwater to the west and north.

The Missouri River floodplain sediments consist of 15 to 20 feet of silt loam to very silty clay having moderate to high permeability. The groundwater table occurs at depths of 15 to 20 feet below floodplain level. Fluctuations of 5 to 15 feet occur during periods of high water levels when there are prolonged wet seasons that affect the Missouri River. Local wet or dry periods cause little effect other than recharge directly through the landfill. This may be the most significant risk posed by the Westlake Landfill, the poor soil covering procedures that apparently occurred during landfill operation.

Beneath the silt loam, very silty clay surface soil of the alluvium, the Missouri River alluvial sediments are characterized by a general increase in grain size associated with increasing depth. The sand increase becomes noticeable at depths of 20 to 30 feet with the percentage of gravel beginning to occur at depths of 30 to 40 feet. These coarse sediments, plus the large and perennial recharge of the river, cause the alluvium to be one of the major and most important aquifers in the state. Consequently, if contamination is occurring from the landfill, it is threatening a vital aquifer resource.

Public Drinking Water Advisory:

There are no public water systems located in the immediate vicinity of Westlake Landfill. However, the site is less than one mile from the Missouri River, which is the water source for St. Louis County Water Company's North Plant. The intake for that plant is about eight miles downstream from Westlake Landfill. Should contamination from the site reach the Missouri River, the downstream public water system could be affected.

Private wells located near the landfill may also be susceptible to contamination.

Health Assessment:

Uranium is reported to cause adverse health effects in two ways: toxic chemical effects including damage to the kidney and liver, pneumoconiosis, pronounced changes in the blood and generalized injury; and radiation effects including lung cancer, osteosarcoma, and lymphoma.

Analysis of the rates of fetal death, low birth weight, and malformations for 1972-1982 showed no rate for the area significantly higher than the state average.

An exposure assessment including a well survey, water sampling, and an administrative exposure questionnaire was completed for the site. This investigation by the Missouri Department of Health has found there are only four wells still in use in the area that are downgradient from the site. One is used only occasionally and one is not used for potable water at all. None of the residents questioned appeared to have any adverse health effects caused by materials disposed of at the site.

Based on available information, a health threat exists due to the effects of low level uranium wastes buried at the site, and the possibility that off-site migration of these materials might occur. While there is no evidence of past or present exposure, the potential for future exposure exists based on the possibility that off-site migration might occur. Sampling and corrective containment and diversion should continue at this site until risk to the public health can more accurately be determined.

NUREG/CR-2722

Radiological Survey of the West Lake Landfill St. Louis County, Missouri

Prepared by L. F. Booth, D. W. Groff, G. S. McDowell, J. J. Adler, S. I. Peck, P. L. Nyerges, F. L. Bronson

Radiation Management Corporation

Prepared for
U.S. Nuclear Regulatory Commission

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Manuscript Completed: April 1982
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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
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ABSTRACT

This report presents the results of a radiological survey of the West Lake Landfill, St. Louis County, Missouri, performed by Radiation Management Corporation during the spring and summer of 1981. Measurements were made to determine external radiation levels, concentrations of airborne contaminants and the identity and concentrations of subsurface deposits. Results indicate that large volumes of uranium ore residues, probably originating from the Hazelwood, Missouri, Latty Avenue site, have been buried at the West Lake Landfill. Two areas of contamination, covering more than 15 acres and located at depths of up to 20 feet below the present surface, have been identified. There is no indication that significant quantities of contaminants are moving off-site at this time.

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I. INTRODUCTION

In August 1980, Radiation Management Corporation (RMC), under contract to the U. S. Nuclear Regulatory Commission (NRC), performed radiological evaluations of four burial grounds[1]. The first of these sites selected for evaluation was the West Lake Landfill in St. Louis County, Missouri. An initial site visit was completed in August 1980, and a preliminary radiological survey was completed in November 1980. The detailed radiological evaluation was performed in the spring and summer of 1981.

The purpose of this survey was to clearly define the radiological conditions of the West Lake Landfill site. The results of this survey should be sufficient to allow an engineering evaluation to be performed to determine whether remedial actions should and can be taken.

The methods used to evaluate this site include the following:

1) measurement of external gamma exposure rates 1 meter above the surfaces and beta-gamma count rates 1 cm above surfaces;
2) measurement of radionuclide concentrations in surface soils;
3) measurement of radionuclide concentrations in subsurface deposits;
4) measurement of gross activity and

radionuclide concentrations in surface and subsurface water samples;

5) measurement of radon flux emanating from surfaces;

6) measurement of airborne radioactivity; and

7) measurement of gross activity in vegetation.

These measurements were performed on-site using two mobile facilities designed by RMC. A small number of samples were returned to the RMC radiological laboratories in Philadelphia for analysis for nuclides which could not be detected in the field, and for quality assurance checks on the field measurements. A set of reference background measurements were made at three locations in the St. Louis area, near West Lake Landfill. In addition, a series of non-radiological measurements were performed to identify the possible presence of toxic or hazardous agents known or believed to have been buried at this landfill.

II. SITE CHARACTERISTICS

The West Lake Landfill is located on St. Charles Rock Road just west of the Taussig Road intersection in Bridgeton, Missouri. The site is about one (1) mile northwest of Route 270 and approximately 1-1/2 miles east of the Missouri River. It is located in a combined rural-industrial area, and is bounded on three sides by farm land and on the fourth by St. Charles Rock Road, beyond which are located several commercial and industrial establishments. The nearest residential area is a trailer park located about 3/4 of a mile southeast of the landfill.

The site is approximately 200 acres and consists of a quarry, stone and limestone processing and storage areas, and several active and inactive landfills (Figure 1), which are open to the public during normal working hours. West Lake Landfill keeps track of entries for the purpose of assessing fees for disposal; however, access is not controlled for other reasons. Users are prohibited from disposing of hazardous materials at this site by current Missouri state law.

Studies indicate the landfill is on the alluvial floodplain of the Missouri River. This fact prompted the Missouri Geological Survey, in 1973, to propose classification of the site as hazardous under the then existing operating procedures. In addition, samples from perimeter monitoring wells taken in 1977 and 1978 indicated some movement of leachate into monitoring wells, based on chemcial (not radiological) analyses. However, recent studies by the Department of Natural Resources indicate little or no surface or sub-surface movement of materials from the site[2]. Leachate from the active sanitary landfill is collected and treated on-site. At this time there is no evidence of significant ground water contamination; however, geological reports indicate a potential for such problems.

In May 1976, the St. Louis Post-Dispatch[3] printed a story alleging that radioactive material had been erroneously dumped in the West Lake Landfill in 1973. The source of this material was identified as the Cotter Corporation, Hazelwood, Missouri, Latty Avenue Site.

An NRC investigation conducted by Region III in 1976 [4] concluded that about 7 tons of U3O8, contained in 8700 tons of leached barium sulfate residues, had been mixed with about 39,000 tons of soil at Latty Avenue and the entire volume disposed of at the West Lake Landfill. The earlier study by the Post- Dispatch (1976) claimed only 9000 tons (presumably the leached barium sulfate residues) had been buried, and that the remaining material had not been disposed of at West Lake. The Post-Dispatch alleged that the contractor hauling the dirt had admitted falsifying invoices for about 40,000 tons of soil. Discussions with site personnel indicated that a large quantity of soil from Latty Avenue had indeed been dumped at West Lake, although the exact amount was unknown.

A fly-over radiological survey (ARMS flight), performed for the NRC in 1978, showed external radiation levels as high as 100 uR/hr in the area indicated by West Lake personnel as containing the Latty Avenue material. In addition, this survey revealed another possibly contaminated zone in a fill area previously believed to be "clean".

Figure 2 shows the results of the 1978 aerial survey. The area in the southeast fill was believed to contain Latty Avenue material, while that on the northeast boundary was previously unidentified.

In addition to radioactive material, it is known that hazardous chemical wastes have been disposed of at this landfill. Since disposal was unregulated prior to 1973, little is known about the actual materials present. However, it is believed that aside from normal landfill materials, there are chemical industrial wastes in the landfill.

Among the chemical wastes believed to be present are:

waste ink	halogenated intermediates
pigments	aromatics
oily sludges	oils
esters	wastewater sludges
alcohols	heavy metals
insecticides	herbicides

III. RADIOLOGICAL SURVEY METHODS

(A) Measurement of External Radiation Levels

The two areas of contamination were gridded and surveyed for both gamma radiation levels at one meter above the surface, and beta-gamma levels at the ground surface.

The basic pattern at each contaminated area was survey blocks defined by a 10 meter grid system. External gamma levels at one meter were recorded at each grid point (i.e. at each intersection of two grid lines). Initially, precise exposure rate measurements at a few specially selected grid points were made with a sensitive Tissue Equivalent Ionization Chamber System (described in Appendix I). At the same time, NaI scintillation detector (described in Appendix I) measurements were made and a conversion factor for the NaI count rate versus uR/hr established (See Figure I-3). Once this factor was confirmed, the scintillation detector was used for all grid measurements at relatively low exposure rates. For the few higher rates encountered, a Geiger-Mueller portable survey instrument was used.

At each grid point, an end window G-M tube (described in Appendix I) was used for surface measurements. An open and closed window reading was made at 1 cm, and the ratio of the two used to indicate the presence or absence of surface contamination.

(B) Measurement of Surface Radioactivity

Based on the external surface measurements, surface soil samples were collected for analysis from both contaminated areas. These samples were collected from locations on-site where surface deposits were indicated, as well as locations where the drainage characteristics indicated the possibility that radioactive materials may have been carried or washed away from original burial locations. The soils were dried, ground and sealed in 500 ml aluminum cans for counting on the intrinsic germanium (IG) gamma ray spectroscopy system (described in Appendix I).

Vegetation on-site consisted only of grass and common weeds. Off-site, crops are grown on farm land immediately north and west of the site. Since the possibility of contamination exists here, crop samples were collected where indicated by surface measurements. These samples were dried, crushed and counted as described above.

(C) Measurements of Subsurface Radioactivity

Since it was known that most, or all, of the radioactive materials at the West Lake Landfill have been buried, extensive subsurface monitoring and sampling was required. The purpose of this activity was to determine the depth and lateral extent of subsurface contamination.

A series of holes through and bordering the contaminated deposits were drilled and lined with 4-inch PVC casing. Each hole was then scanned with a 2" by 2" NaI(Tl) scintillation detector and rate meter system.

Representative holes were then logged using an *in situ* gamma measurement system consisting of an intrinsic germanium (IG) detector coupled to a multichannel analyzer (described in Appendix I). Field analyses were then made, both qualitatively and quantitatively, thereby eliminating time consuming laboratory analyses and expensive core sampling of each hole. Measurement intervals ranged from 6" to 24", depending upon factors such as hole depth and activity. An occasional core sample was taken to verify the *in situ* measurements and to confirm the presence or absence of non-gamma emitting nuclides such as Th-230.

(D) Measurement of Radioactivity in Water

Whenever possible, water samples were taken from the bore holes and two off-site monitoring wells. Samples were also taken from standing water, run off water, and leachate liquids. Samples were filtered, evaporated and counted for gross activity, or were filtered and sealed in Marinelli beakers for gamma spectroscopic analysis.

(E) Measurement of Airborne Radioactivity

Measurements were made to determine if the material buried on-site is a source of airborne radioactivity. The isotopes of concern are Ra-226, Ra-224 and/or Ra-223, which decay to Rn-222, Rn-220 and Rn-219. Th emanation of radon from the soil, and movement of radon and daughters off-site.

These measurements may be used to determine Rn flux emanation as a source term for off-site dose calculations, or as an indication of the presence of radium at or below the surface. Additional on-site Rn daughter measurements were made to perform working level (WL) determinations.

Radon flux measurements which are to be related to off-site dose calculations were of no value for Rn-219, due to its very short (4 sec) half-life. Therefore, only its long-lived daughters are of concern for off-site exposures. In addition, if the parent (Ra-223) is not within a few millimeters of the surface, Rn-219 is not likely to emanate into the atmosphere [5].

Due to these considerations, only Rn-222 and Rn-220 fluxes were measured. The principal measurement technique was collection of a filtered gas sample from an accumulator and subsequent counting in a radon gas analyzer (described in Appendix 1). Sequential alpha counting, starting immediately after sampling, allowed separation of Rn-222 from Rn-220 (if present). Repetitive samples were taken from several locations during the survey period in an effort to evaluate the effect of fluctuations between individual measurements, due to varying meteorological and soil conditions. A second method using charcoal canisters was also employed as a check on the accumulator technique.

The presence of Rn-219 was determined by detection of its daughters deposited on high volume particulate sample filters, using gamma spectroscopy. Total Rn daughter levels were also estimated by gross alpha activity on particulate filters. From this, a total working level (WL) determination was made.

IV. SURVEY RESULTS

(A) External Radiation Levels

Two areas of elevated external radiation levels have been identified by this survey. Figure 3 shows the two areas as they existed in November, 1980, at the time of the preliminary RMC site survey. As can be seen, both areas contained locations where levels exceeded 100 uR/hr at 1 meter, and in Area 2, gamma levels as high as 3-4 mR/hr were detected. The total areas exceeding 20 uR/hr were about 3 acres in Area 1 and 9 acres in Area 2.

External gamma levels measured in May and July of 1981 are shown in Figure 4. These levels had decreased significantly, especially in Area 1, due to continuing activities at the landfill. In both cases, contaminated areas were covered with additional fill material. RMC estimates that about 4 feet of sanitary fill was added to the entire area denoted as Area 1, and that an equal amount of construction fill was added to most of Area 2. As a result, only a small region of a few hundred square meters in Area 1 exceeds 20 uR/hr. In Area 2, the total area exceeding 20 uR/hr decreased by about 10%, and the highest levels are now about 1600 uR/hr, near the Shuman building.

Both areas were marked off in a 10 m by 10 m grid, based on a north-south line erected from a boundary marker, as laid out by a surveying team, as a reference line. Grid designations are shown in Figures 5 and 6. At each grid point, external gamma levels at 1 m, and beta-gamma count rates at 1 cm, were measured. Results of these measurements are given in Tables 1 and 2.

Beta-gamma measurements at 1 cm from the surface are given in count rates, rather than dose rates, due to the difficulty in measuring beta dose rates accurately with end window G-M tubes. Large differences between open- and closed-window readings indicate the possibility of surface contamination. Little surface contamination was found in Area 1, as would be expected due to fresh land fill cover over nearly the entire area.

Several isolated spots of surface contamination in Area 2 were indicated by beta-gamma measurements, and later confirmed by surface soil sampling. These spots are generally located near the northwest edge of Area 2, which includes the berm that bounds the landfill at that point. Some erosion and run-off is evident along the top of the fill, apparently uncovering deposits of radioactive material in the process. Thus far, fresh construction fill has not been added here, due to the inaccessibility of these spots.

A second region of surface contamination is found just north of the Shuman building. It is not clear why material appears on the surface here, except that it is possible that some digging or excavation has occurred here in the past.

(B) Surface Soil Analyses

A total of 61 surface soil samples were gathered and analyzed on-site for gamma activity. Samples were normally stored 10 to 14 days to allow ingrowth of radium daughters. Concentrations of U-238, Ra-226 (from PB-214 and Bi-214), Ra-223, Pb-211 and Pb-212 were determined for each sample. Locations of surface soil samples are shown in Figures 7 and 8, and the results in Table 3.

In all soil samples nothing other than uranium and/or thorium decay chain nuclides and K-40 was detected. Off-site background samples were on the order of 2 pCi/g for Ra-226. On-site samples ranged from about 1 to 21,000 pCi/g Ra-226, and from less than 10 to 2,100 pCi/g U-238. In those cases where elevated levels of Ra-226 were detected, the concentrations of U-238 were generally anywhere from a factor of 2 to 10 lower. In cases of elevated sample activity, daughter products of both U-238 and U-235 were found.

In general, surface activity was limited to Area 2, as indicated by the surface beta-gamma measurements. Only two small regions in Area 1 showed contamination, both located near the access road across from the site offices.

In addition to on-site gamma analyses, a set of 12 samples were submitted to the RMC radiochemical laboratories for thorium and uranium radiochemical determinations. The results of these measurements are shown in Table 4. They show that all samples contain high levels of Th-230. The ratio of Th-230 to Ra-226 (Bi-214) is about 20, which indicates an "enrichment" of thorium in these residues, as discussed in Section V.

(C) Subsurface Soil Analysis

Subsurface contamination was assessed by extensive "logging" of holes drilled through the landfill at locations known or thought to contain radioactive materials. Several holes were drilled in areas known to contain contamination, then additional holes were drilled outward in all directions until no further contamination was encountered. A total of 43 holes were drilled, (11 in Area 1 and 32 in Area 2), including 2 off-site water monitoring wells. All holes were drilled with a 6-inch auger and lined with 4-inch PVC casing. The location of these auger holes is shown in Figures 9 and 10.

Each hole was scanned with a 2-inch by 2-inch NaI(Tl) detector and rate meter system for an initial indication of the location of subsurface contamination. Based on the initial scans, certain holes were selected for detailed gamma logging using the IG detector and MCA. A total of 19 holes were logged in this manner.

The results of the NaI(Tl) counts and IG analyses are shown in Table 5. Concentrations of Bi-214, as determined by the IG system, ranged from less than 1 to 19,000 pCi/g. For those holes where both NaI(Tl) and IG counts were made, a good correlation between gross NaI(Tl) counts and Ra-226 concentrations, as determined by in situ analysis of the daughter Bi-214 by the IG system, was found. Figure 11 is a plot of NaI(Tl) count rate versus IG determination of Ra-226, and shows a nearly linear relationship between the two at concentrations near the action criteria. The conclusion is that the NaI(Tl) data is a good estimation of the Ra-226 concentration in soil, so long as the radionuclide mix is reasonably constant. In the case of West Lake Landfill, this has been shown to be the case.

It was determined that the subsurface deposits extended beyond areas where surface radiation measurements exceeded action criteria. Figures 12 and 13 show the approximate area of subsurface contamination versus the area of elevated surface radiation levels. The total difference in areas is on the order of 5 acres.

The variations of contamination with depth are shown in Figure 14. As can be seen, the surface elevations vary by about 20 feet, with the highest elevations at locations of fresh fill. Contamination (> 5 pCi/g Ra-226) is found to extend from the surface, in several areas, to a depth of about 20 feet below surface, in two cases. In general, the subsurface contamination appears to be a continuous single layer, ranging from two to fifteen feet thick, located between elevations of 455 feet and 480 feet and covering 16 acres total area.

In Figures 15-19, representations of the subsurface deposits are provided based on auger hole measurements. These representations are consistent with the operating history of the site, which suggests that the contaminated material was moved onto the site within a few days' time, and spread as cover over fill material. Thus, one would expect a fairly continuous, thin layer of contamination, as indicated by survey results.

(D) Water Analyses

A total of 37 water samples were taken during this survey, 4 in the fall of 1980, and the remainder in the spring and summer of 1981. Results of water analyses are shown in Table 6.

None of the sample alpha activities exceeded the MPC for Ra-226 (the most restrictive nuclide present) in water for unrestricted areas. Only one sample exceeded the EPA gross alpha activity guidelines for drinking water and that was a sample of standing water near the Shuman building. Several samples, including all the leachate treatment plant samples, exceeded the EPA gross beta drinking water standards. Subsequent isotopic analyses indicated that all the beta activity can be attributed to K-40. None of the off-site samples exceeded either EPA standard.

(E) Airborne Radioactivity Analyses

Both gaseous and particulate airborne radioactivity were sampled and analyzed during this study. Since it was known that the buried material consisted partially or totally of uranium ore residues, the sampling program concentrated on measuring radon and daughters in the air. Two methods were used: the first was a scintillation flask method for radon gas and the second was analysis of filter paper activity for particulate daughters.

A series of grab samples using the accumulator method (described in Appendix I) were taken between May and August of 1981. A total of 111 samples from 32 locations were collected. Results can be found in Table 7. Radon flux levels ranged from 0.2 pCi/sq.m-s in low background areas to 868 pCi/sq.m-s in areas of surface contamination.

At three locations, repetitive measurements were made over a period of two months. These results are plotted in Figure 20. As can be seen, significant fluctuations were observed at two locations. The fact that these fluctuations were real and not measurement artifacts was later confirmed by duplicate charcoal canister samples, as described below.

A total of 35 charcoal canister samples were gathered at 19 locations over a three month period. The results are listed in Table 8, and show levels ranging from 0.3 pCi/sq.m-s to 613 pCi/sq.m-s. On 24 different occasions, the charcoal canisters and accumulator were placed in essentially the same locations, at the same time, for duplicate sampling. The results of this side-by-side study are presented in Table 9, and show generally good correlation between the two methods.

A set of 10 minute high volume particulate air samples were taken to determine both short-lived radon daughter concentrations and long-lived gross alpha activity. Sample results are shown in Table 10. The highest levels were detected in November, 1980, near and inside the Shuman building. Only these two samples exceed MPC for radon daughters for unrestricted areas.

In addition to the routine 10 minute samples, five 20 minute high volume air samples were taken and counted immediately on the IG gamma spectroscopy system. The purpose of these analyses was to detect the presence of Rn-219 daughters. All samples were taken near surface contamination and are listed in Table 11. In addition to Rn-222 daughter gamma activities, Rn-219 daughters were detected by measuring the low abundance gamma rays of Pb-211. Concentrations of Rn-219 daughters ranged from 6E-11 uCi/cc to 9E-10 uCi/cc.

(F) Vegetation Analysis

Vegetation samples included weed samples from on-site locations and farm crop samples (winter wheat) from the northwest boundary of the landfill. This location was chosen due to possible run off from the fill into the farm field. No elevated activities were found in these samples.

(G) Non-Radiological Analysis

Six composite samples were submitted to the RMC Environmental Chemistry Laboratory for priority pollutant analysis. Five samples were taken from auger holes (one from Area 1 and four from Area 2) and the sixth from the West Lake leachate treatment plant sludge. The results, shown in Table 12, indicate a significant presence of organic solvents in Area 2 samples. The results of the leachate sludge analysis were not as high as any of the soil samples.

A chemical analysis of radioactive material from both areas was also performed by RMC labs and reported in Table 13. Results show elevated levels of barium and lead in most cases.

(H) Background Measurements and Remedial Action Criteria

Various off-site locations were selected for reference background measurements. The results of these measurements are summarized in Table 14, and can be compared with the established NRC target criteria for remedial action, for this project, shown in Table 15.

V. CONCLUSIONS

Based on survey results, it is evident that the West Lake Landfill contains two areas of surface and/or subsurface contamination. These deposits yield detectable external radiation levels in both areas. However, only an area of less than 0.1 acre in Area 1 exceeds 20 uR/hr, while about 8 acres in Area 2 exceeds the 20 uR/hr criteria. The highest reading detected in the most recent survey was 1.6 mR/hr in Area 2, near the Shuman Building.

Analyses of soil samples from both areas, as well as in situ measurements, show that the contaminants present at West Lake consist of uranium and uranium daughters. Chemical analyses reveal high concentrations of barium and sulfates in the radioactive deposits. These results tend to confirm the reports that this contaminated material is uranium and uranium ore, contained in leached barium sulfate residues, and presumably transferred from the Latty Avenue Site in Hazelwood, Missouri.

Analysis of soils also shows a high Th-230 to Ra-226 ratio. Since the target criteria for Ra-226 is the most restrictive of those contaminants present, it has been assumed that Ra-226 would be the controlling radionuclide for remedial action determinations. However, since Th-230 levels may be from 5 to 50 times higher than Ra-226 concentrations, this assumption may be erroneous. It is likely that high concentrations of thorium resulted from separation of both uranium and radium from the ores, thus "depleting" the ores of uranium and radium, or, "enriching" the residues in thorium. This "enrichment" would also be evident in the U-235 chain, despite the short half-lives of Th-227 and Th-231, since the long-lived Pa-231 would remain in the residues. The concentrations of Pa-231, inferred from Ra-223 determinations, are also shown to be high.

Auger hole measurements show that nearly all the contamination present is located below the landfill surface,although a few locations near the northwest berm in Area 2 show surface, or near surface, deposits. These deposits range from 2 to 15 feet in thickness, and appear to form a contiguous layer covering an area of about 14 acres (68,000 sq.yd.) in Area 2 and about 2 acres (10,000 sq.yd.)in Area 1. If an average thickness of 2 yards is assumed, the estimated total volume is 150,000 cu.yd., which corresponds to roughly 170,000 tons of soil. This implies that if the source of contamination was the Latty Avenue material, the original volume of 40,000 tons has been diluted by a factor of about 4, which is not unexpected, with the continual movement and spreading of materials during fill operations.

As discussed previously, the auger hole measurements detected deposits exceeding 5 pCi/g Ra-226 within a few feet of the surface, in areas where surface external radiation levels were indistinguishable from normal background levels.

These results confirm suspected difficulties in detecting buried materials with surface measurements, even when using relatively sensitive portable survey instruments.

At no time has radioactivity in off-site water samples been above any applicable guidelines. These results indicate that the buried ore residues are probably not soluble and are not moving off-site via ground water. On-site samples have shown some gross beta activity above EPA drinking water guidelines (attributable to K-40); however, gross alpha and Ra-226 levels are within limits. The absence of significant contamination in the leachate liquid or sludge is consistent with the implication that the buried material is not moving through the landfill.

As would be expected, radon flux emanation rates were highest at locations of surface, or near surface, contamination. At locations where the material is covered by several feet of fill, flux levels are near background rates.

Particulate air samples established indicated the presence of Rn-222 and Rn-219 daughters near the locations of surface deposits. However, concentrations are very low, and do not exceed allowable levels for unrestricted areas, except in one location. In general, cover of a few feet of fill reduces airborne concentrations to near background levels.

The fact that West Lake is an active landfill presents several serious problems for performing radiological assessments and remedial actions. In the first place, as the landfill conditions change, so do the surface radiological characteristics. These changes were evident in the reduction of radiation levels in Area 1 between November 1980, and May 1981. It is possible that future landfill activities will obscure all detectable surface radiation levels at the site.

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[1] U. S. Nuclear Regulatory Commission Letter Contract: NRC-02-080-034, August 13, 1980.

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[3] St. Louis Post-Dispatch, May 30, 1976.

[4] U. S. Nuclear Regulatory Commission, Office of Inspection and Enforcement, Region III, IE Inspection Report No. 76-01, June and August, 1976.

[5] Crawford, D. J., "Radiological Characteristics of Rn-219", Health Physics, Vol. 39, No. 3, pp. 450.

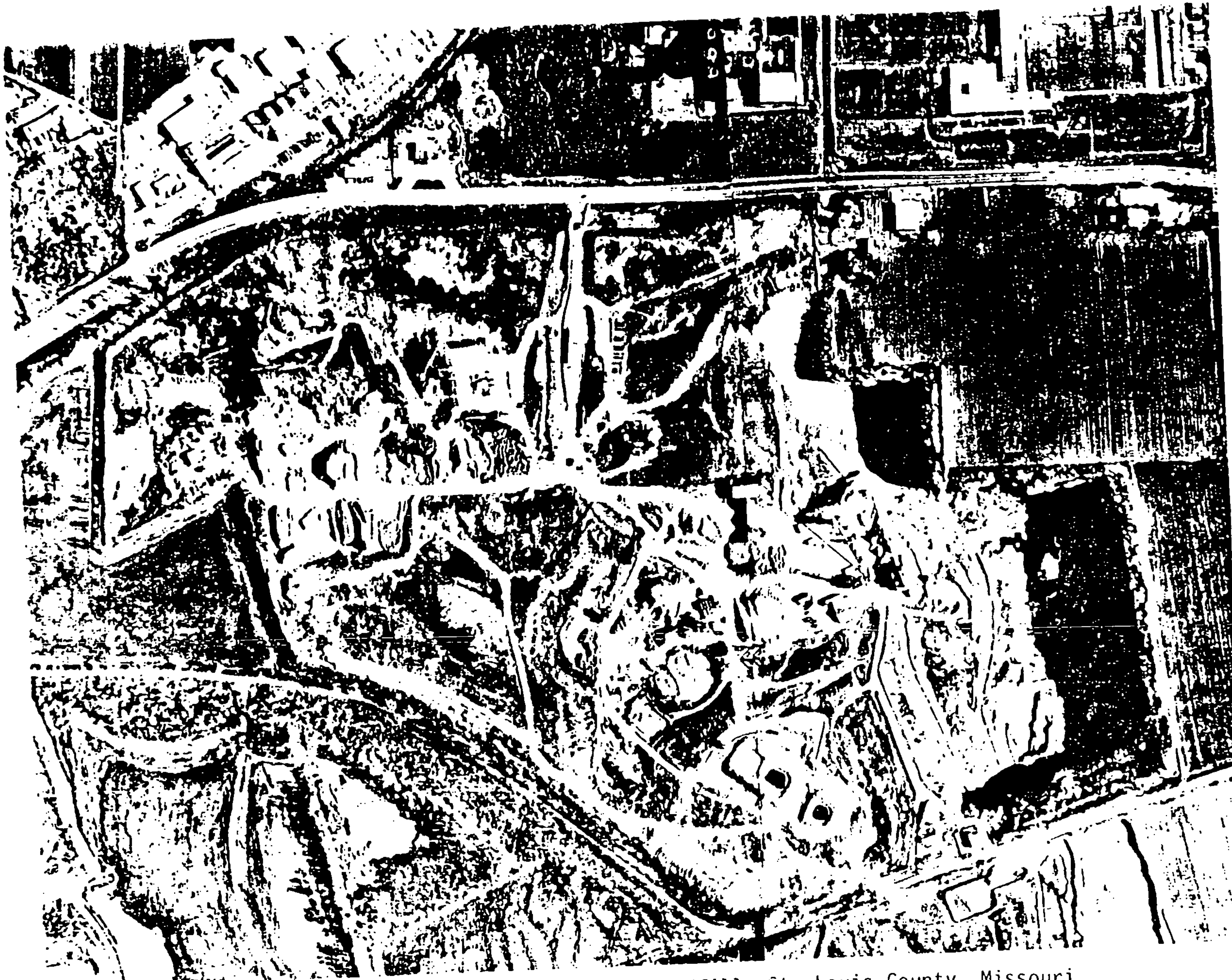
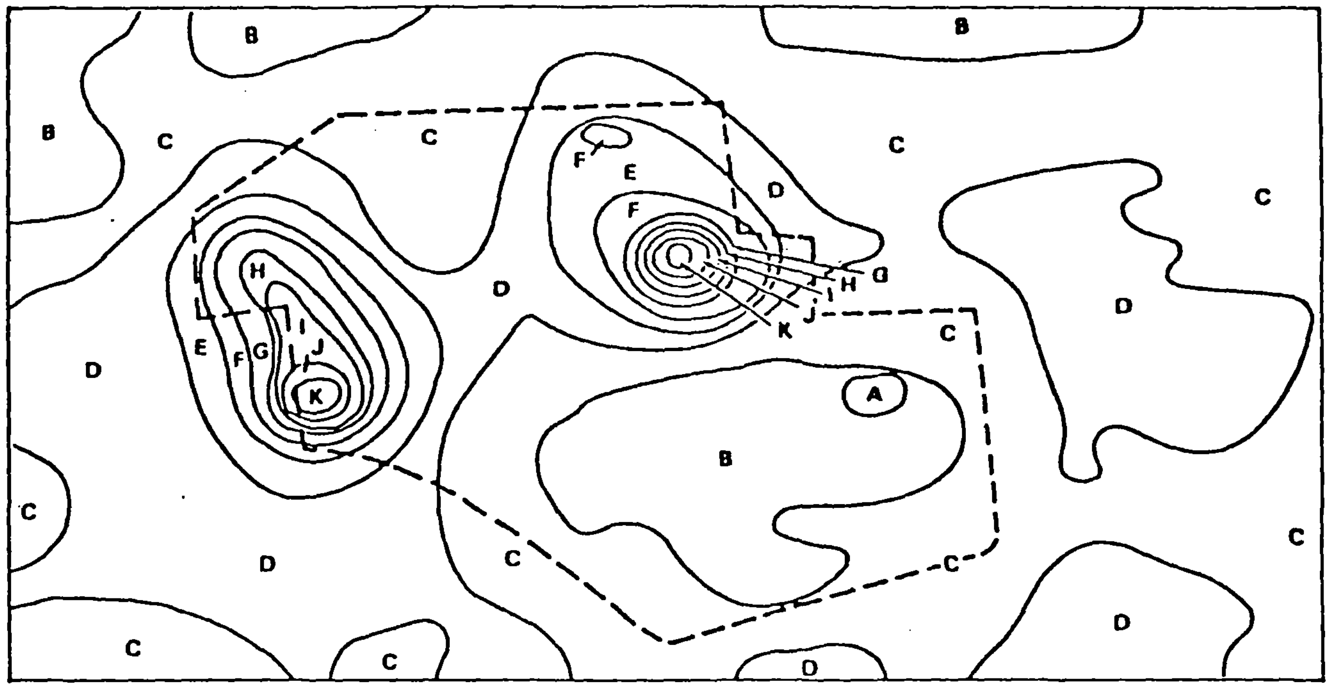
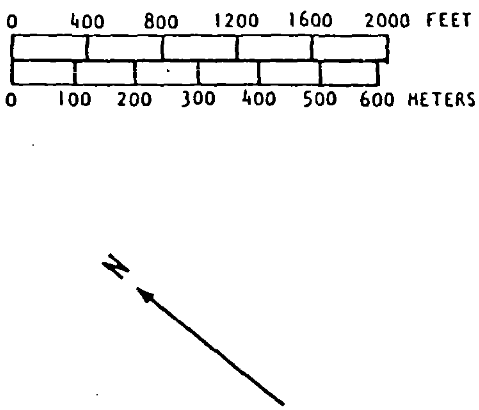


Figure 1. Aerial view of West Lake Landfill, St. Louis County, Missouri





- - - - - ESTIMATED LANDFILL OUTLINE

GROSS COUNT CONVERSION SCALE	
LETTER LABEL	GAMMA EXPOSURE RATE* 1 m LEVEL (μR/hr)
A	~ 6
B	6 - 8
C	8 - 10
D	10 - 13
E	13 - 17
F	17 - 24
G	24 - 33
H	33 - 45
I	45 - 62
J	62 - 84
K	84 - 116

*AVERAGED OVER DETECTABLE FIELD-OF-VIEW AT 60 m ALTITUDE AND EXTRAPOLATED TO THE 1 m LEVEL INCLUDES 3.7 μR/hr COSMIC RADIATION.

Figure 2. West Lake Landfill aerial survey isopleths.

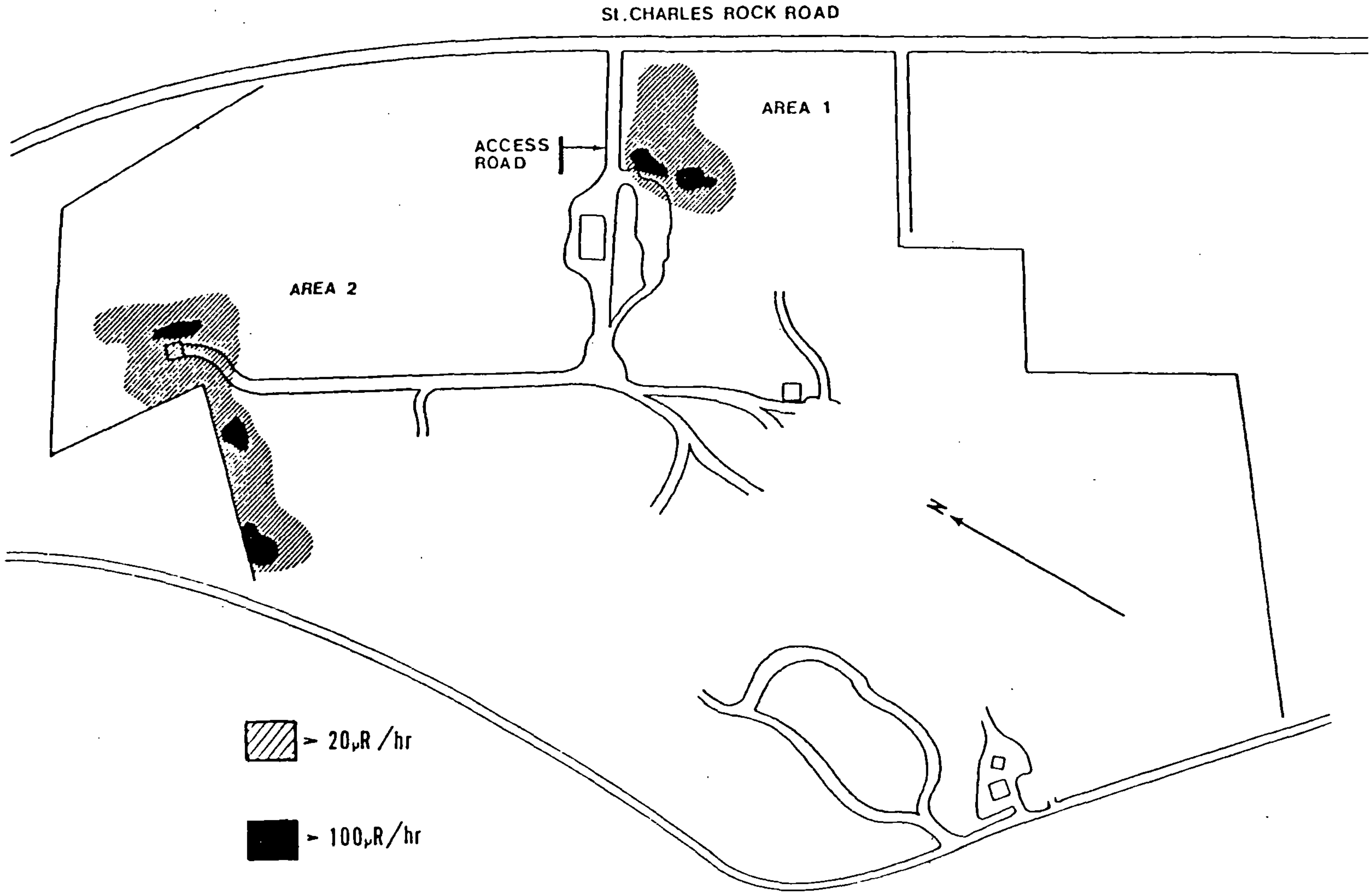


Figure 3. External gamma radiation levels, November 1980.

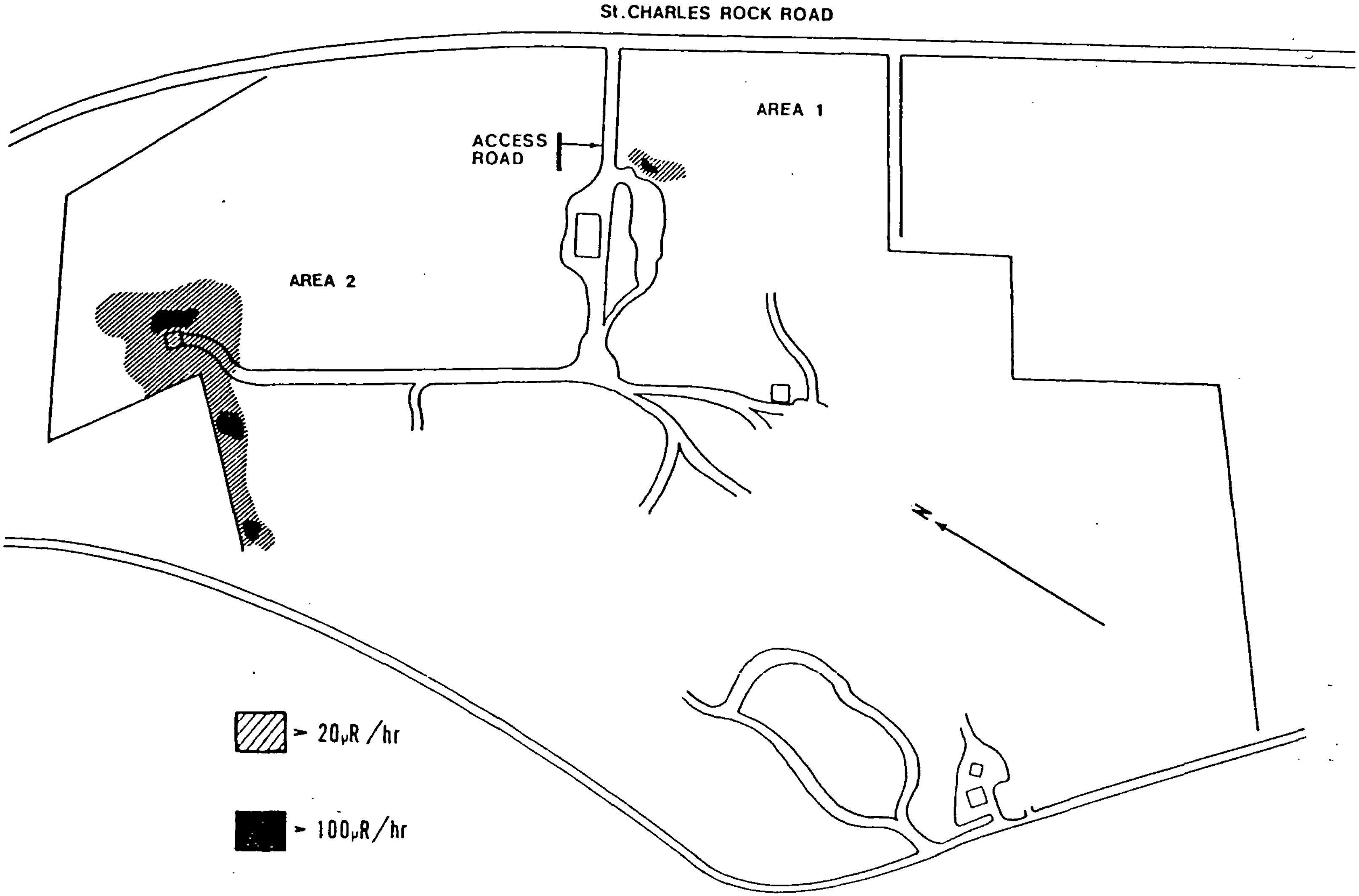


Figure 4. External gamma radiation levels, May, 1981

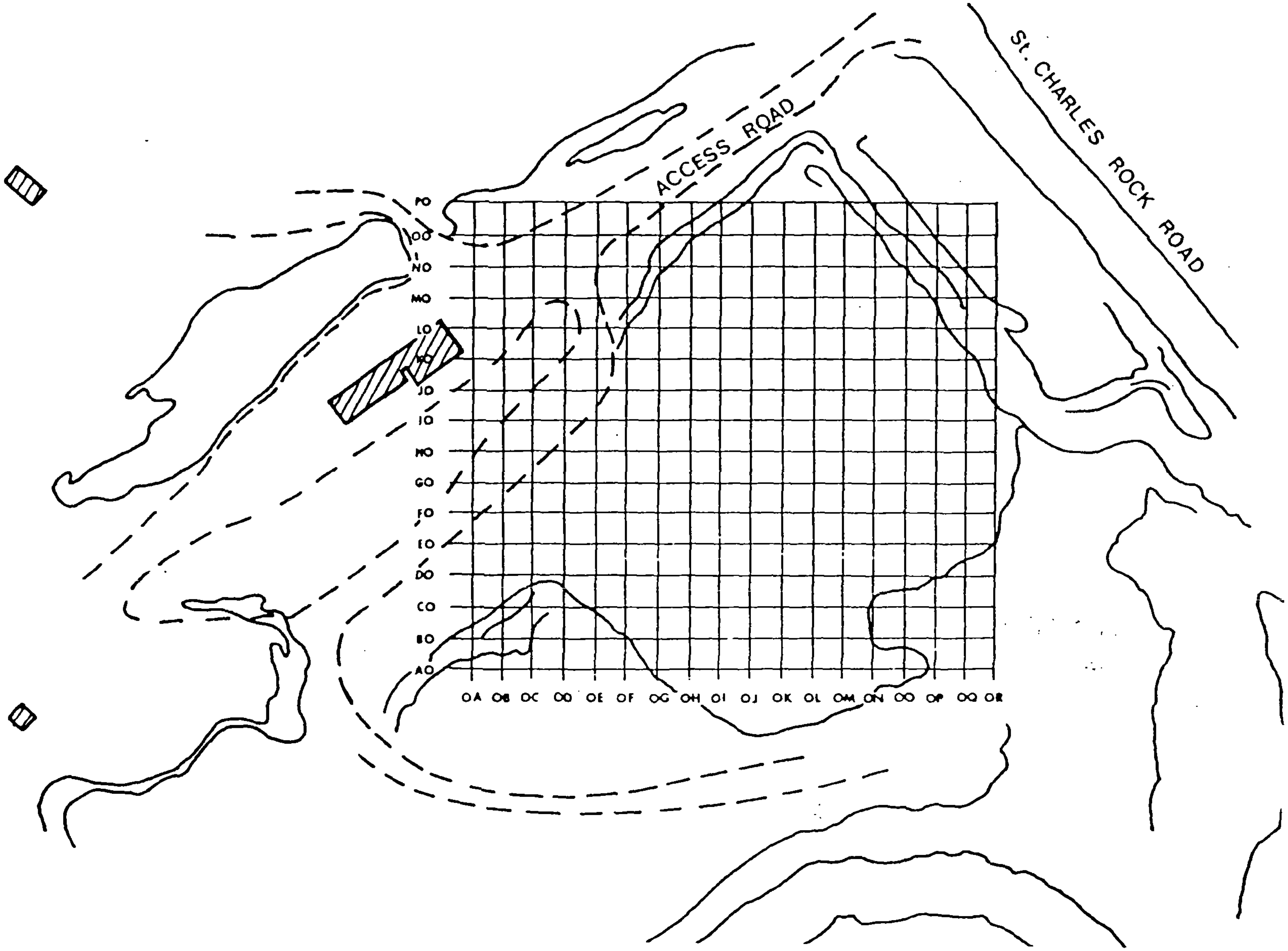


Figure 5. Grid locations for radiological survey, Area 1.

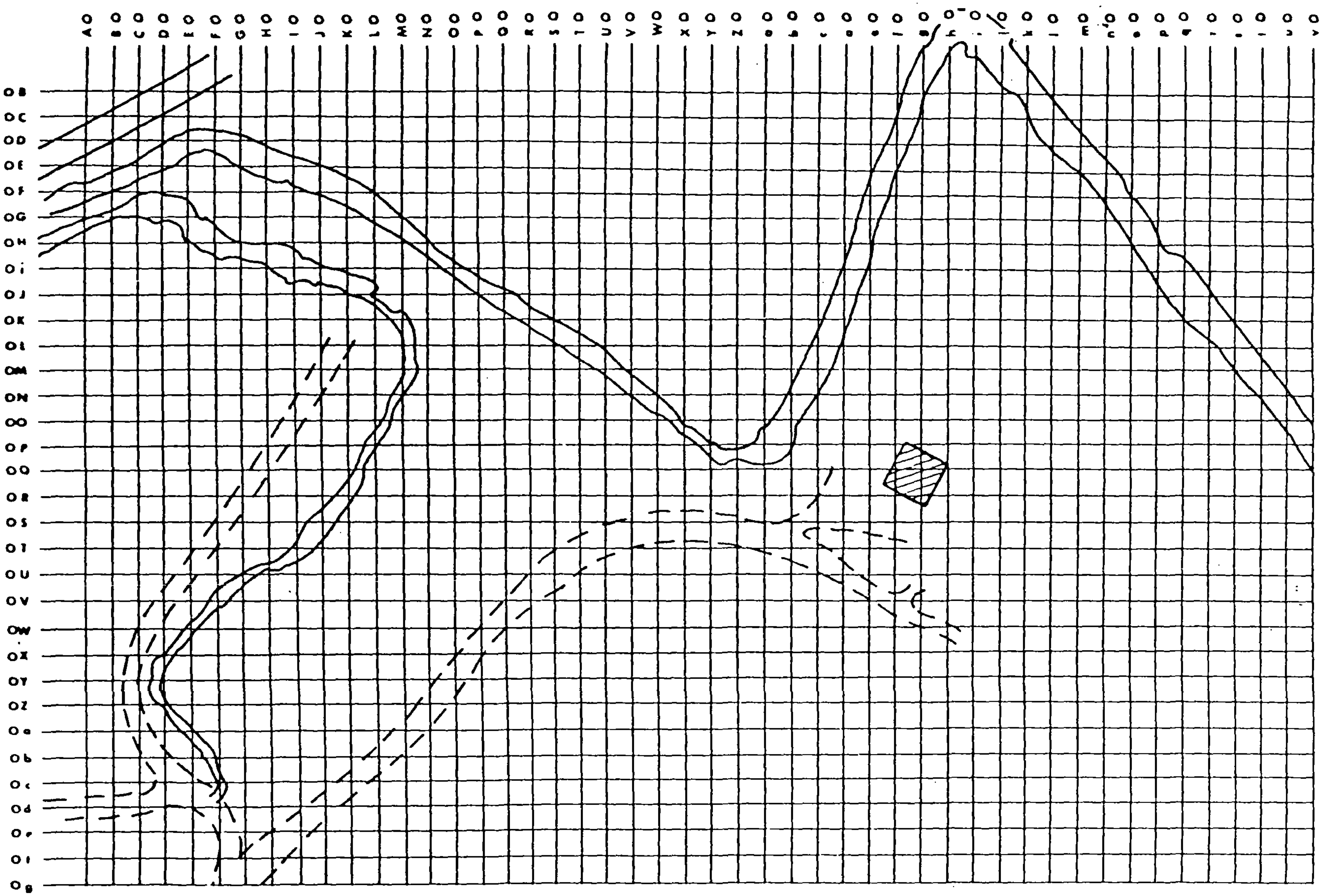


Figure 6. Grid locations for radiological survey, Area 2.

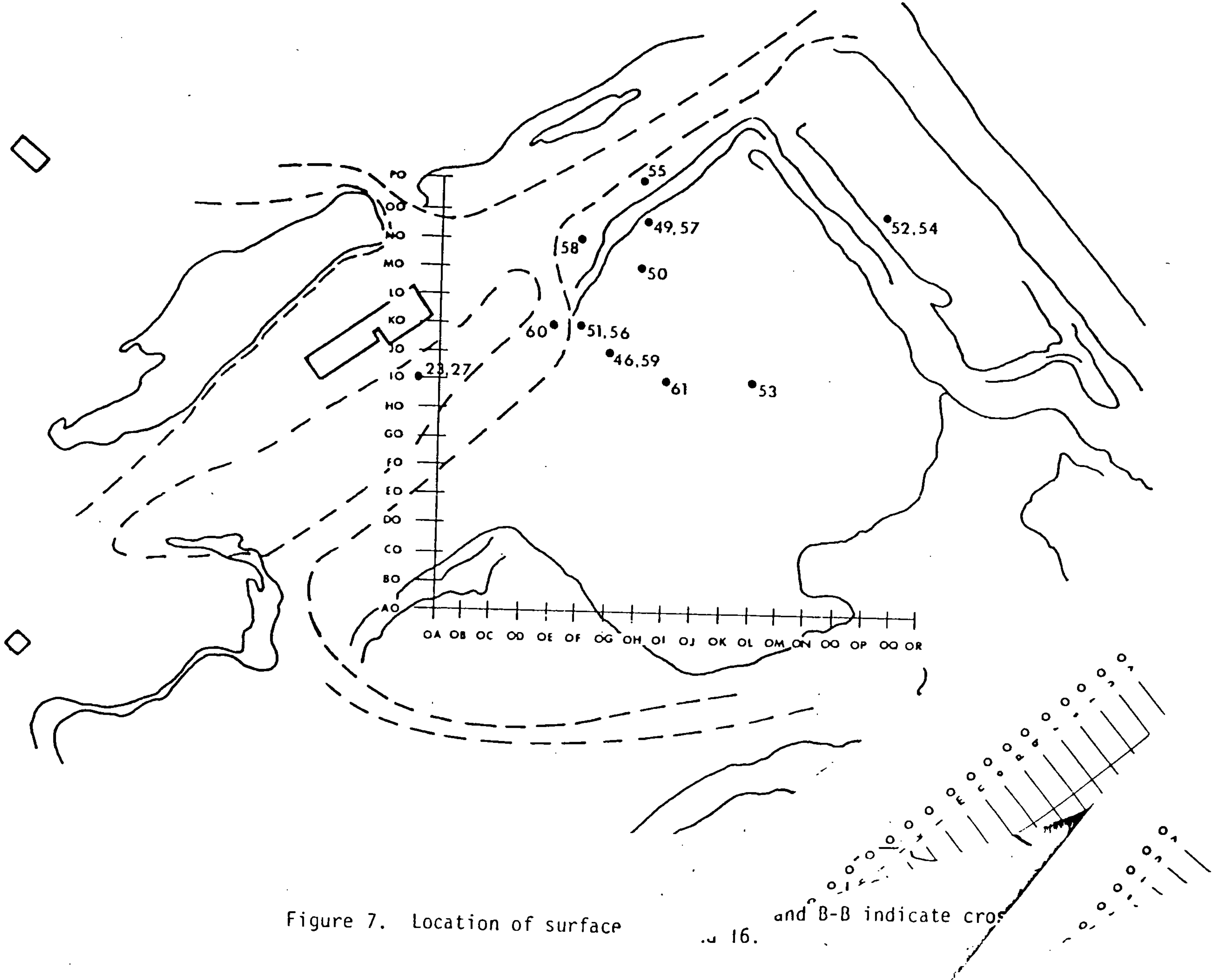


Figure 7. Location of surface ... and B-B indicate cros... ...d 16.

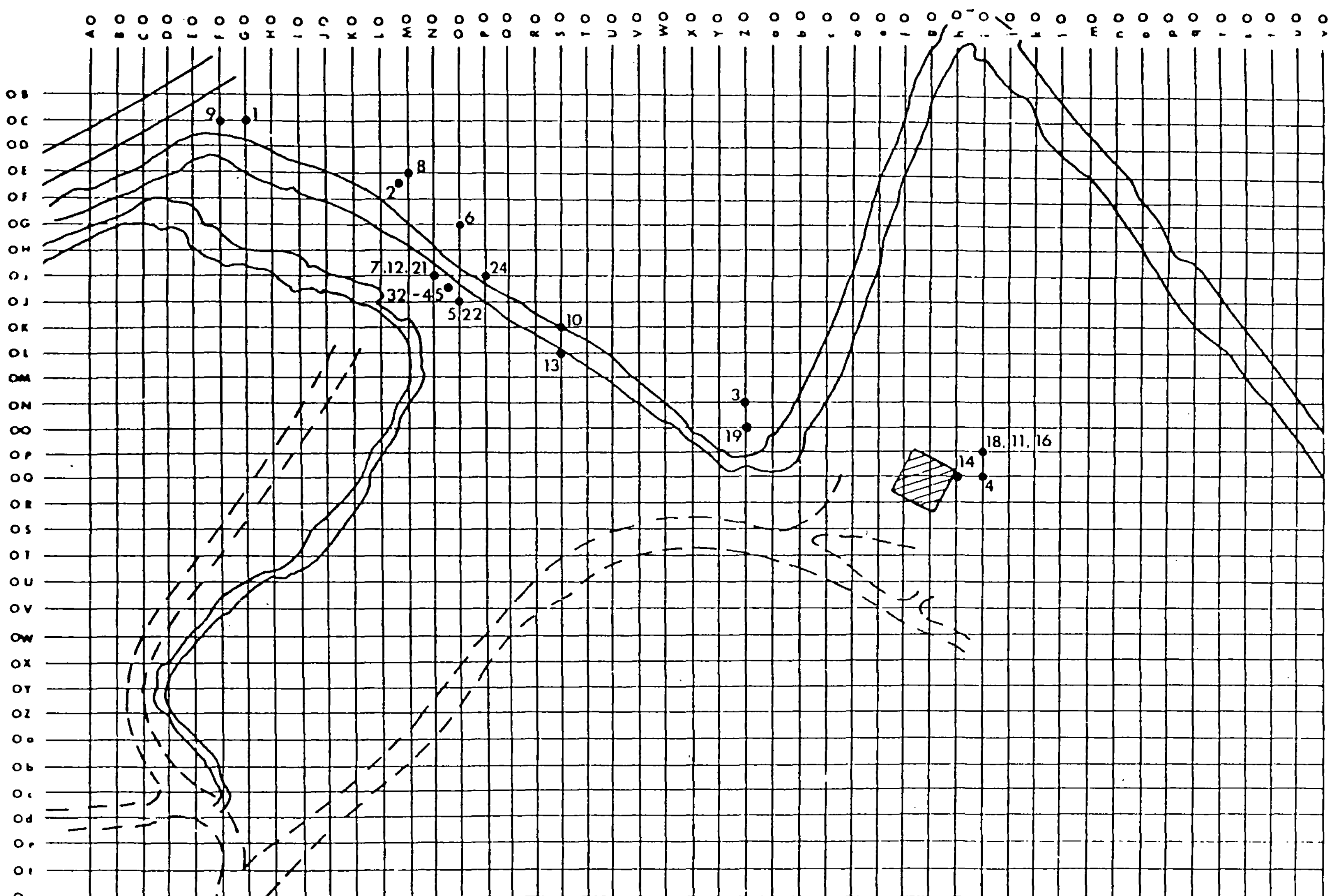


Figure 8. Location of surface soil samples, Area 2.

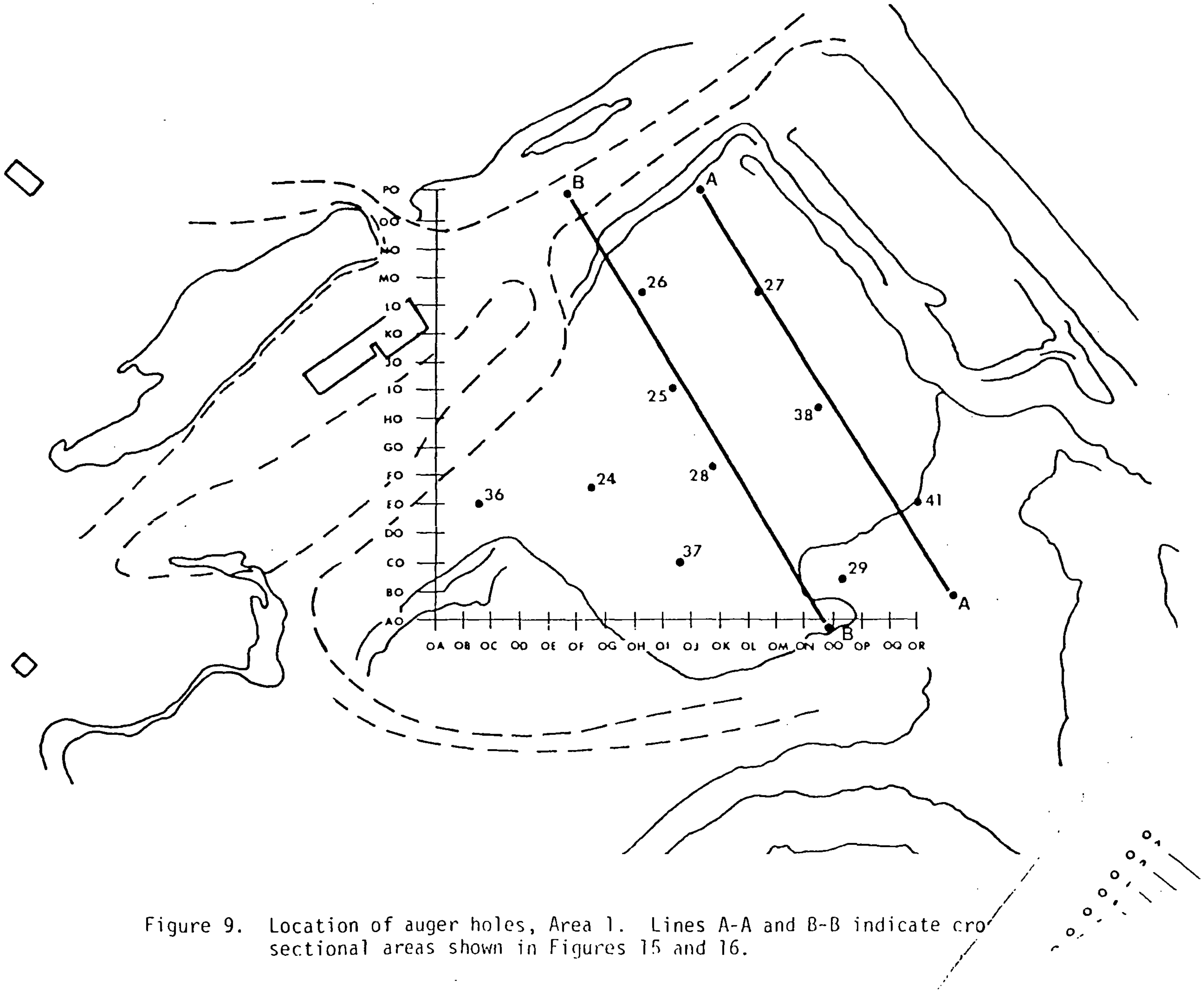


Figure 9. Location of auger holes, Area 1. Lines A-A and B-B indicate cro sectional areas shown in Figures 15 and 16.

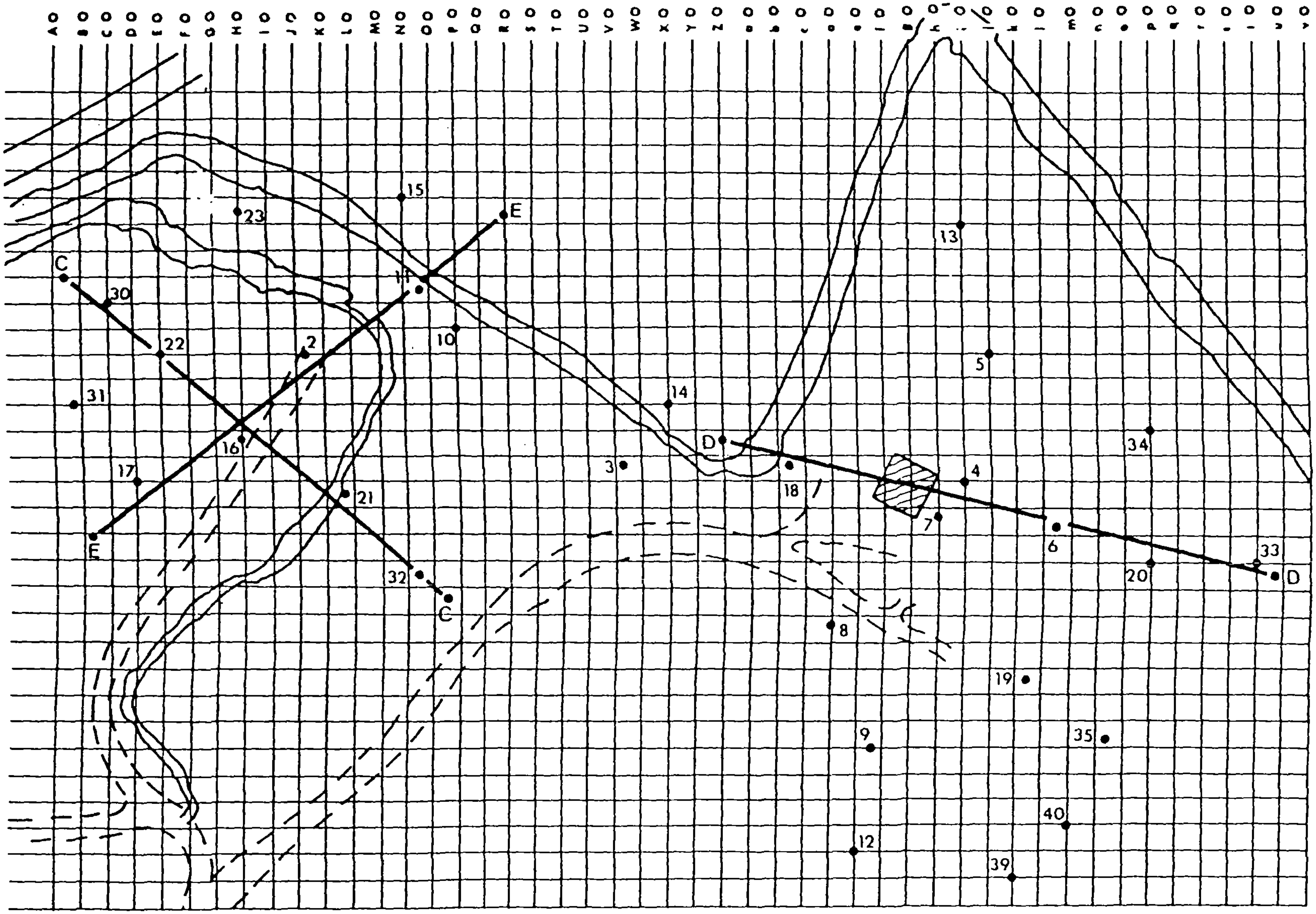


Figure 10. Location of auger holes, Area 2. Lines C-C, D-D, and E-E indicate cross sectional areas shown in Figures 17, 18, and 19.

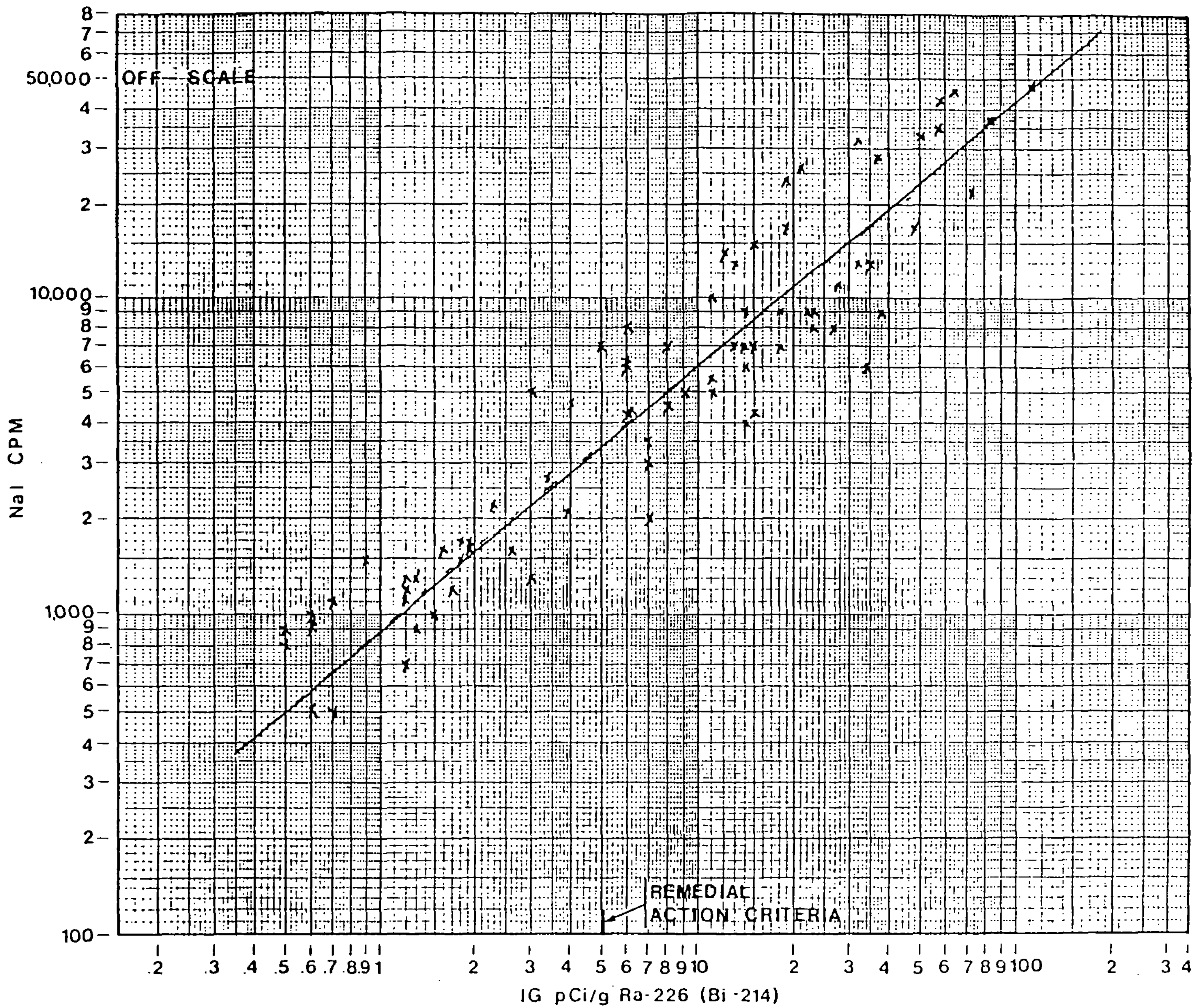


Figure 11. Auger hole NaI (Tl) count rate versus Ra-226 concentration, as determined by the I.G. in situ measurements. Data is from bore holes 16, 32, 22, 21, 31, 6, 19 and 20.

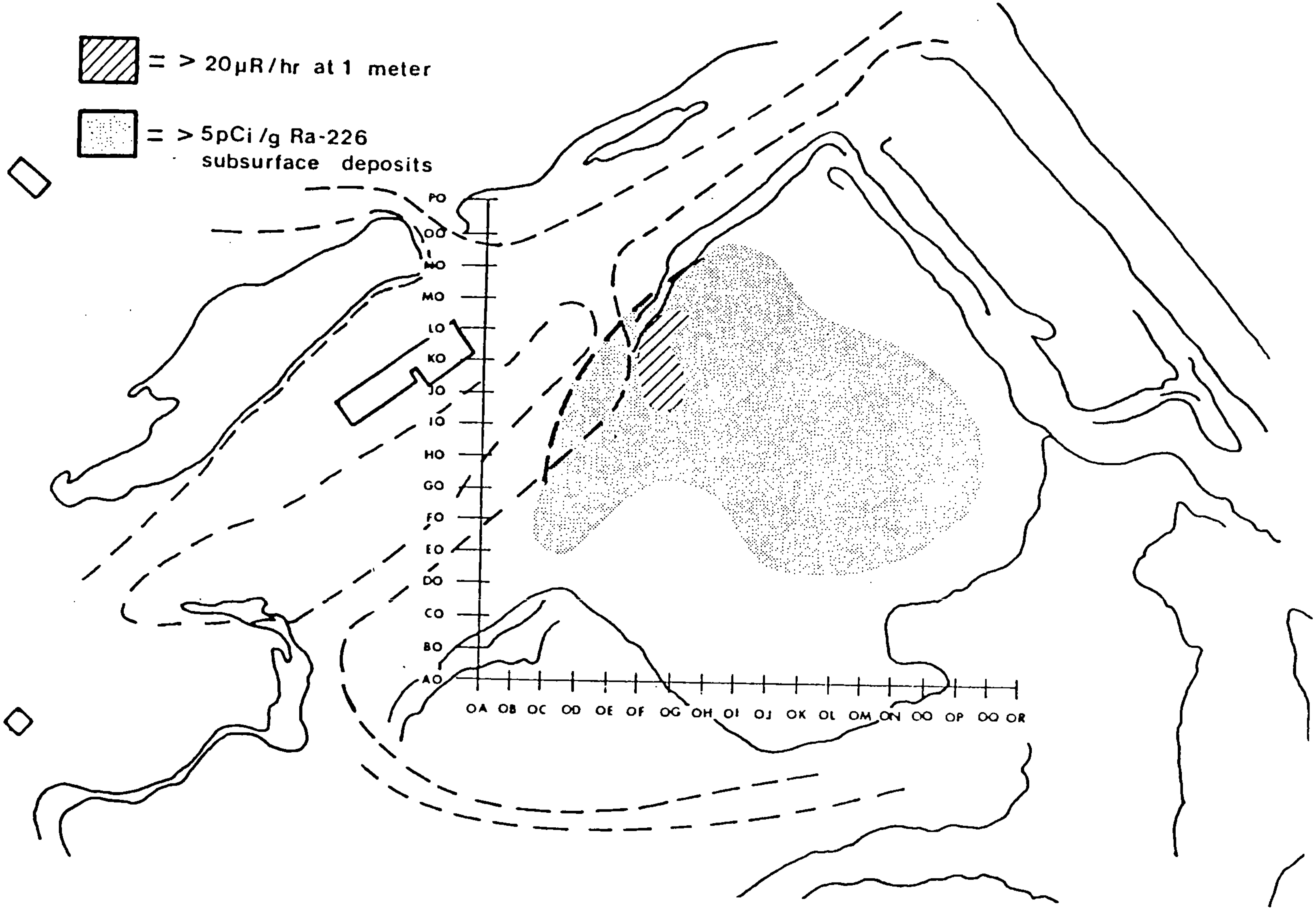


Figure 12. Location of subsurface contamination and surface radiation levels, Area 1. The shaded area shows a lateral contour for 5pCi/g Ra-226, regardless of depth. The cross hatched area shows the surface locations which exceed 20uR/hr at 1 meter.

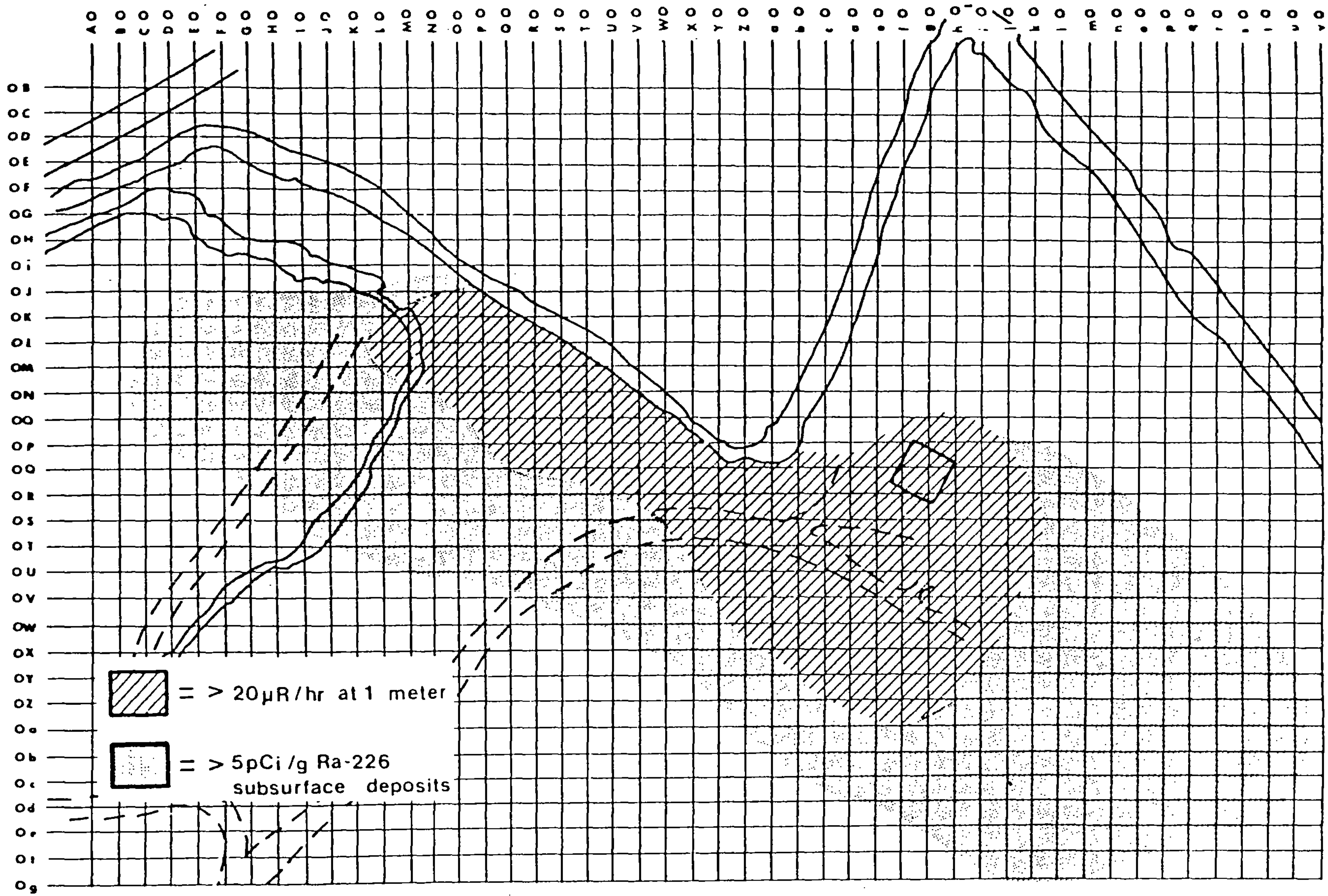


Figure 13. Location of subsurface contamination and surface radiation level, Area 2. The shaded area shows a lateral contour for 5pCi/g Ra-226, regardless of depth. The cross hatched area shows the surface location which exceeds 20uR/hr at 1 meter.

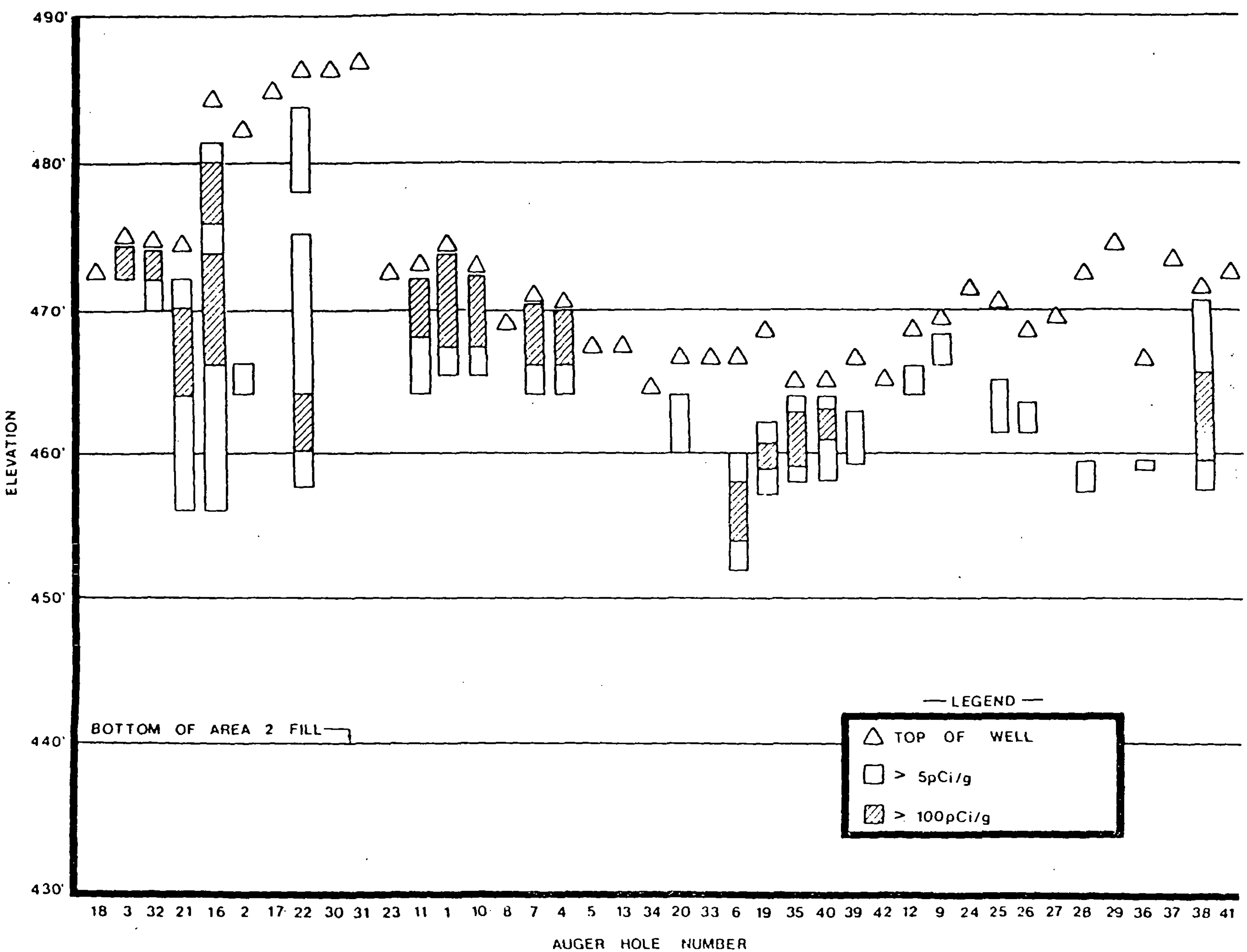


Figure 14. Auger hole elevations and location of contamination within each hole.

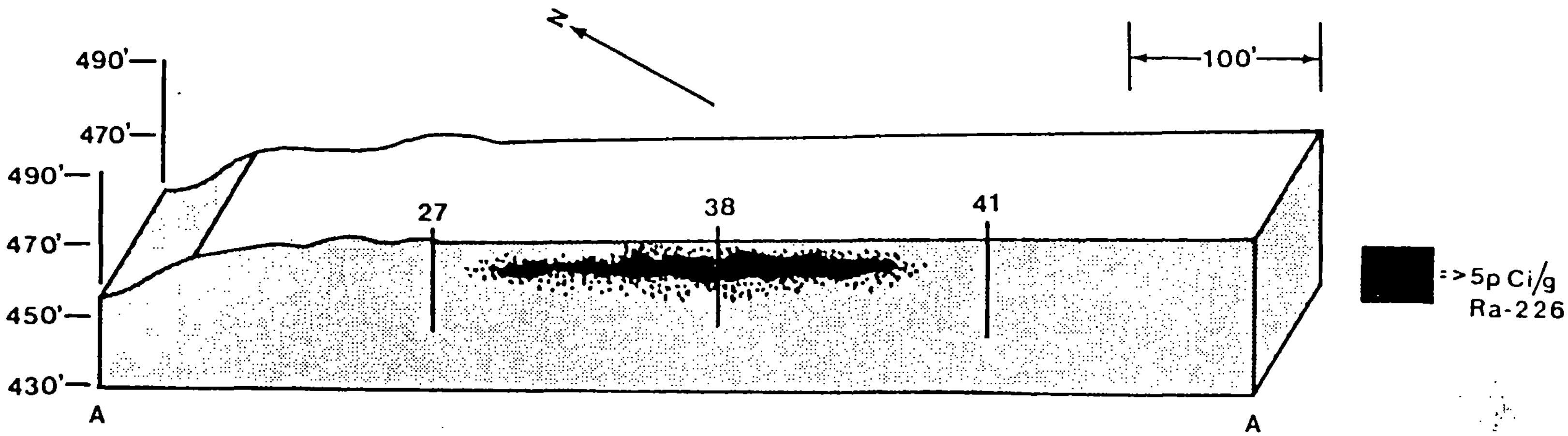


Figure 15. Cross section A-A (from Figure 9) showing subsurface deposits in Area 1. The blackened areas indicate the estimated extent of contamination exceeding 5pCi/g Ra-226, based on surface and auger hole measurements.

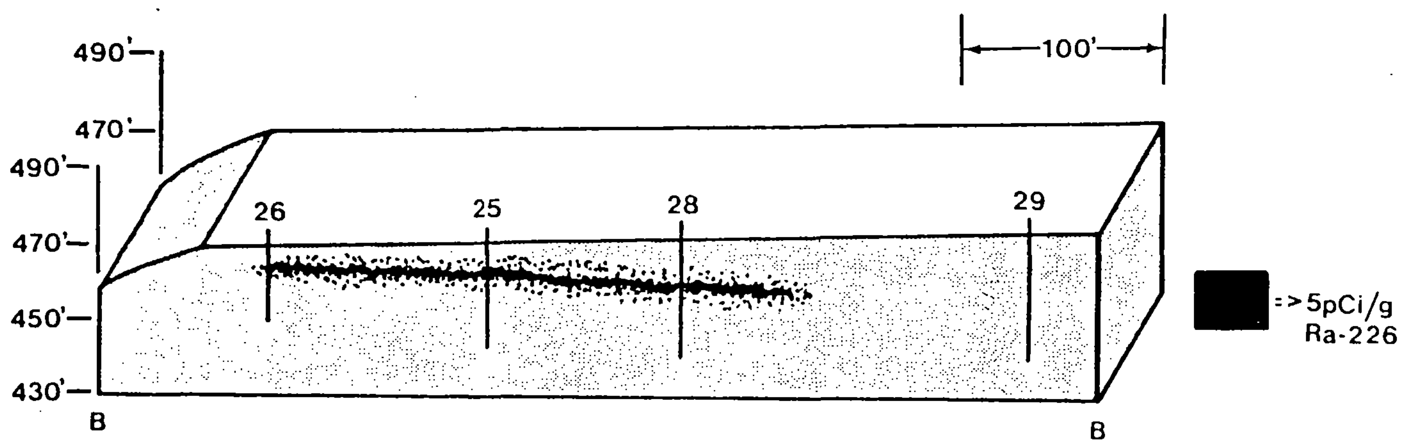


Figure 16. Cross section B-B (from Figure 9) showing subsurface deposits in Area 1. The blackened areas indicate the estimated extent of contamination exceeding 5pCi/g Ra-226, based on surface and auger hole measurements.

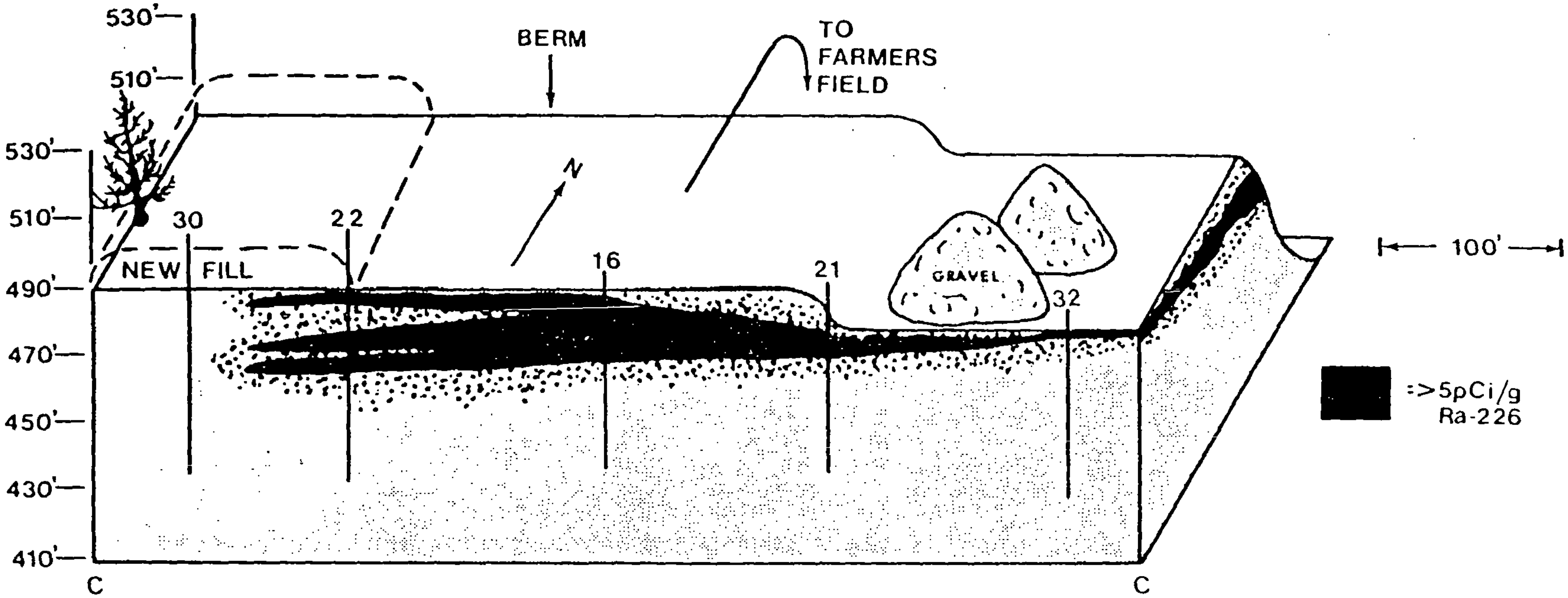


Figure 17. Cross section C-C (from Figure 10) showing subsurface deposits in Area 2. Blackened areas indicate the estimated location of contamination exceeding 5pCi/g Ra-226, based on surface and auger hole measurements.

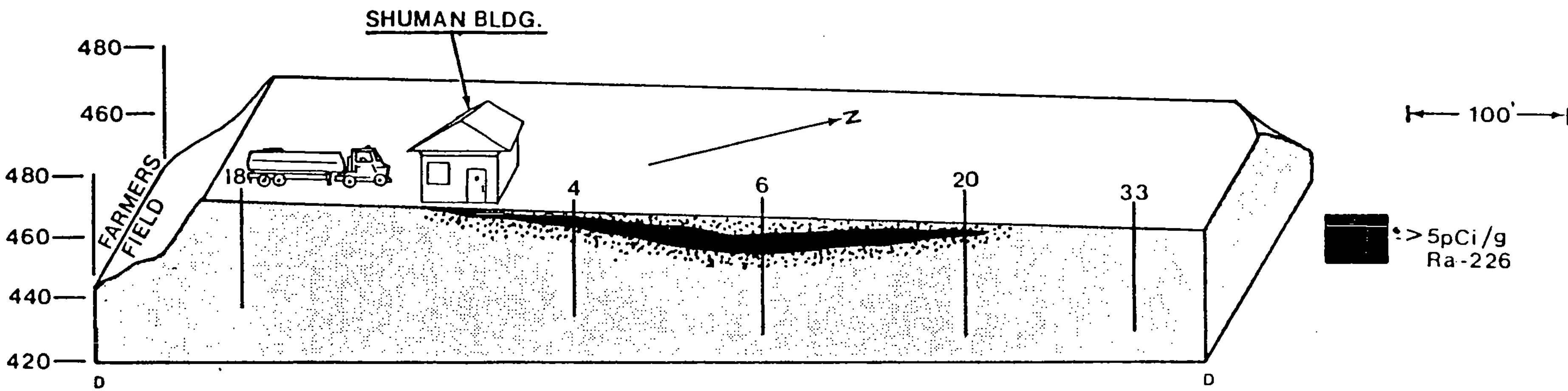


Figure 18. Cross section D-D (from Figure 10) showing subsurface deposits in Area 2. Blackened areas indicate the estimated location of contamination exceeding 5pCi/g Ra-226, based on surface and auger hole measurements.

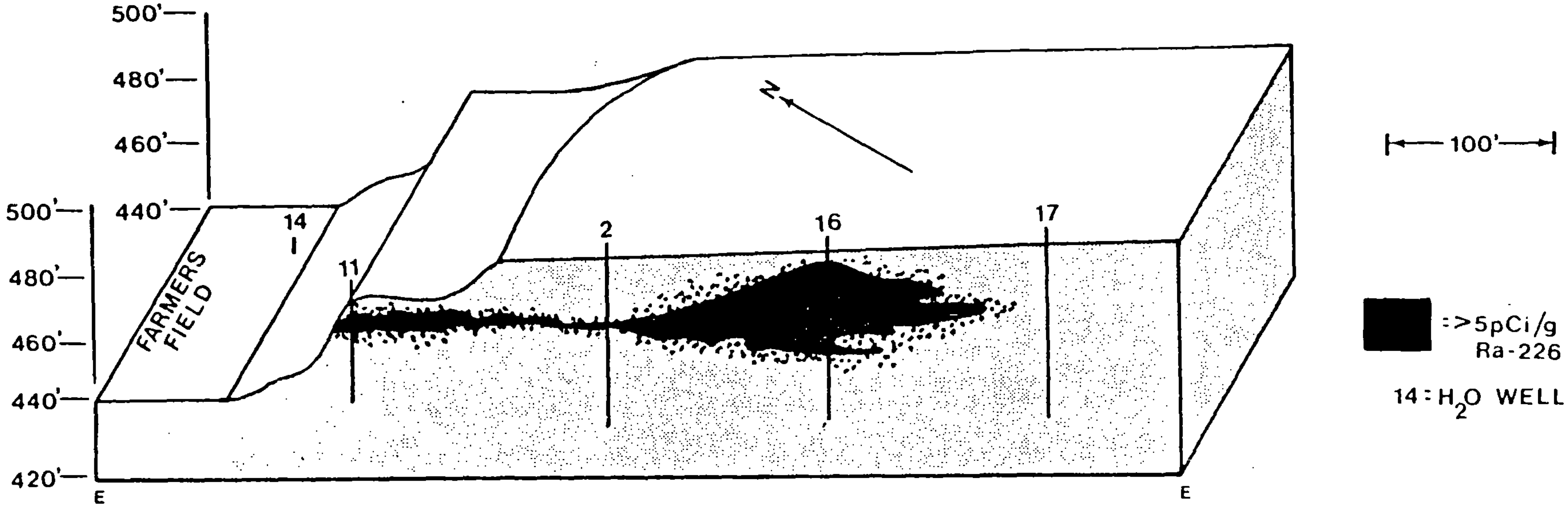


Figure 19. Cross section E-E (from Figure 10) showing subsurface deposits in Area 2. Blackened areas indicate the estimated location of contamination exceeding 5pCi/g Ra-226, based on surface and auger hole measurements.

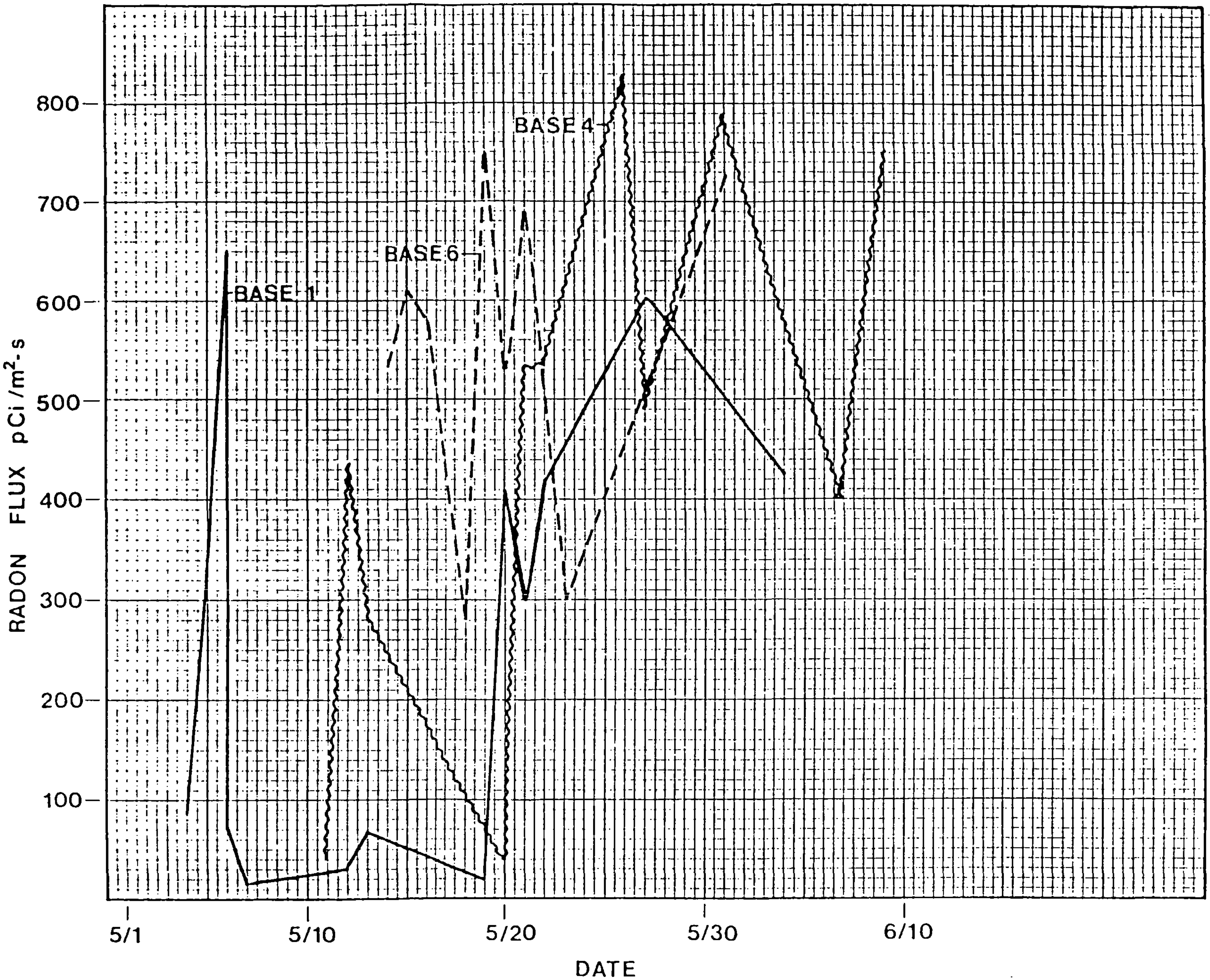


Figure 20. Radon-222 flux measurements at three locations in Area 2, for May, 1981.

Table 1

Gamma Radiation Levels and Beta-Gamma
Count Rates at Grid Locations in Area 1

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
G00E	1000	10	30	40
H00E	900	9	60	50
I00E	1200	11	30	50
J00E	800	8	40	40
K00E	800	8	20	30
L00E	1200	11	20	30
M00E	800	8	40	40
N00E	760	7	40	30
P00H	1100	10	50	50
P00I	1200	11	40	30
Q00I	1000	10	50	50
P00J	1100	10	50	50
Q00J	1200	11	40	60
P00K	1100	10	40	30
Q00K	1200	11	30	50
C00F	900	9	40	50
D00F	900	9	30	40
E00F	1100	10	40	50
F00F	1200	11	30	40
G00F	900	9	40	40
H00F	1000	10	40	40
I00F	1200	11	40	40
J00F	2000	16	40	50
K00F	2700	20	50	50
L00F	2100	17	40	60
M00F	1500	12	60	60
N00F	1000	10	40	60
O00F	800	8	30	30
E00G	1100	10	20	30
F00G	1000	10	30	60
G00G	900	9	40	40
H00G	1000	10	20	40
I00G	1200	11	30	30
J00G	1000	10	30	40
K00G	1600	13	60	70
L00G	1300	11	40	50
M00G	2200	17	60	50
N00G	1300	11	30	40
O00G	-	-	50	40
E00H	1100	10	40	40
F00H	900	9	30	30
G00H	1100	10	30	50
H00H	1200	11	50	40
I00H	1000	10	40	50

Table 1, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
J00H	1000	10	50	40
K00H	1000	10	20	50
L00H	1100		20	50
M00H	1200	11	50	40
N00H	1500	12	50	80
O00H	-	-	40	40
E00I	1000	10	40	30
F00I	1000	10	30	40
G00I	800	8	30	30
H00I	1000	10	50	40
I00I	1100	10	30	60
J00I	1000	10	30	40
K00I	900	9	30	40
L00I	1000	10	30	40
M00I	900	9	40	40
N00I	1100	10	40	40
O00I	1100	10	30	50
E00J	1100	10	40	60
F00J	1200	11	30	40
G00J	1300	11	50	40
H00J	1200	11	50	50
I00J	1100	10	50	50
J00J	1000	10	30	30
K00J	1100	10	40	40
L00J	1000	10	40	50
M00J	1200	11	50	40
N00J	900	9	40	30
O00J	900	9	40	40
E00K	1000	10	50	50
F00K	900	9	40	50
G00K	1000	10	50	50
H00K	1100	10	50	60
I00K	800	8	50	50
J00K	900	9	40	40
K00K	900	9	40	40
L00K	1000	10	30	30
M00K	900	9	30	60
N00K	800	8	30	40
O00K	900	9	40	40
E00L	800	8	40	60
F00L	1000	10	50	50
G00L	900	9	40	40
H00L	900	9	40	60
I00L	1000	10	50	50
J00L	1000	10	50	60
K00L	1000	10	50	50
L00L	900	9	20	30

Table 1, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (UR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
M00L	1100	10	30	40
N00L	1000	10	50	40
O00L	900	9	20	40
F00M	900	7	30	40
G00M	1100	10	20	30
H00M	1000	10	30	40
I00M	1000	10	40	50
J00M	800	8	30	40
K00M	1000	10	40	40
L00M	1100	10	40	30
M00M	1000	10	30	30
N00M	1000	10	30	50
O00M	1000	10	30	40
F00N	900	9	30	50
G00N	1000	10	30	30
H00N	1100	10	30	30
I00N	900	9	40	30
J00N	900	9	40	50
K00N	800	8	40	60
L00N	900	9	40	30
M00N	1100	10	30	30
G00O	1000	10	40	60
H00O	1100	10	20	30
I00O	1000	10	20	30
J00O	1200	11	30	40
K00O	1000	10	40	50

Table 2

Gamma Radiation Levels and Beta-Gamma Count Rates at Grid Locations in Area 2

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
B00F	600	10	40	40
C00E	600	10	20	20
C00F	600	10	20	30
C00G	700	11	30	40
D00B	800	12	-	-
D00C	800	12	-	-
D00D	700	11	20	40
D00E	500	9	20	20
D00F	600	10	20	20
D00G	700	11	30	50
D00H	800	12	50	50
D00I	700	11	30	50
D00J	1100	15	30	40
E00A	500	9	-	-
E00B	800	12	-	-
E00C	800	12	-	-
E00D	700	11	-	-
E00E	700	11	30	30
E00F	500	9	20	20
E00G	500	9	30	30
E00H	800	12	30	40
E00I	700	11	30	30
E00J	900	13	30	30
F00A	800	12	-	-
F00B	900	13	-	-
F00C	800	12	40	40
F00D	900	13	30	30
F00E	1000	14	30	40
F00F	500	9	30	30
F00G	800	12	40	40
F00H	700	11	50	50
F00I	800	12	30	40
F00J	800	12	30	30
G00A	800	12	-	-
G00B	900	13	-	-
G00C	800	12	30	40
G00D	900	13	40	40
G00E	700	11	30	40
G00F	1000	14	30	40
G00G	1000	14	40	40
G00H	800	12	30	40
G00I	800	12	30	30
G00J	800	12	20	40
H00A	800	12	-	-

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
H00B	800	12	-	-
H00C	800	12	30	30
H00D	1000	14	30	40
H00E	900	13	40	40
H00F	800	12	30	30
H00G	800	12	30	40
H00H	700	11	30	30
H00I	600	10	30	30
H00J	900	13	30	30
H00K	800	12	40	60
H00L	800	12	30	50
I00A	900	13	-	-
I00B	1000	14	-	-
I00C	1000	14	30	30
I00D	900	13	40	40
I00E	800	12	40	40
I00F	800	12	20	40
I00G	900	13	30	40
I00H	800	12	30	30
I00I	600	10	40	40
I00J	900	13	40	40
I00K	900	13	40	60
I00L	1100	15	40	80
J00A	900	13	-	-
J00B	800	12	-	-
J00C	900	13	-	-
J00D	1000	14	30	50
J00E	900	13	40	40
J00F	1200	16	30	40
J00G	1000	14	40	40
J00H	800	12	40	40
J00I	600	10	40	50
J00J	900	13	30	30
J00K	900	13	40	40
J00L	600	10	30	30
K00B	1000	14	-	-
K00C	1100	15	-	-
K00D	1200	16	40	50
K00E	1100	15	40	60
K00F	2000	23	30	40
K00G	1400	18	40	40
K00H	1000	14	40	40
K00I	1000	14	40	60
K00J	800	12	20	30
K00K	800	12	30	30
K00L	800	12	20	40
L00B	1000	14	-	-

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
L00C	1100	15	-	-
L00D	1800	21	50	50
L00E	2600	27	40	40
L00F	2500	27	940	1000
* L00G	>50000	640	2100	2200
L00H	7000	55	70	120
L00I	2300	25	140	140
L00J	1300	17	40	80
L00K	2100	24	50	50
L00L	700	11	40	60
* L73E	>50000	400	-	-
M00B	1100	15	-	-
M00C	1500	19	-	-
M00D	1900	22	-	-
M00E	3700	35	80	80
M00F	8000	60	80	90
M00G	3600	35	50	50
M00H	5000	44	40	50
M00I	7000	55	80	90
M00J	1800	21	60	70
M00K	900	13	30	40
M00L	900	13	30	60
N00B	1200	16	-	-
N00C	1300	17	-	-
N00D	1600	20	-	-
N00E	2000	23	-	-
N00F	3300	32	-	-
N00G	1000	14	30	40
N00H	1000	14	40	50
N00I	47000	210	680	1020
N00J	2300	25	30	30
N00K	1000	14	40	50
N00L	900	13	30	50
O00C	1200	16	-	-
O00D	1100	15	-	-
O00E	1400	18	-	-
O00F	1400	18	50	60
O00G	900	13	40	40
O00H	1000	14	40	50
O00I	900	13	20	40
* O00J	>50000	840	4800	5200
O00K	1500	19	50	50
O00L	600	10	20	20
P00D	1100	15	-	-
P00E	1200	16	-	-
P00F	1000	14	40	60
P00G	1000	14	30	50

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
P00H	1100	14	30	50
P00I	1000	14	50	60
P00J	1000	14	400	50
P00K	20000	115	240	300
P00L	3300	32	130	130
P00M	500	9	-	-
P00N	500	9	-	-
Q00E	1000	14	-	-
Q00F	900	13	-	-
Q00G	1000	14	30	40
Q00H	1000	14	30	40
Q00I	800	12	30	60
Q00J	800	12	30	40
Q00K	800	12	30	40
Q00L	1200	16	40	40
Q00M	1300	17	70	70
Q00N	600	10	20	40
R00F	1000	14	-	-
R00G	900	13	-	-
R00H	900	13	40	40
R00I	1000	14	30	30
R00J	800	12	40	40
R00K	900	13	40	40
R00L	1000	14	60	60
R00M	700	11	40	40
R00N	700	11	40	50
R00O	600	10	20	30
S00G	800	12	-	-
S00H	900	13	30	60
S00I	900	13	40	50
S00J	1000	14	50	60
S00K	900	13	40	40
S00L	1200	16	40	40
S00M	6000	48	80	80
S00N	500	9	30	30
S00O	2300	25	90	90
S00P	800	12	30	40
T00G	800	12	-	-
T00H	1100	15	-	-
T00I	1000	14	-	-
T00J	900	13	30	50
T00K	1000	14	30	40
T00L	1000	14	40	40
T00M	1600	20	60	70
T00N	2500	27	180	200
T00O	3100	31	70	70
T00P	16000	98	600	700

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
T00Q	1500	19	30	40
T00R	500	9	30	40
T00S	700	11	-	-
U00H	700	11	-	-
U00I	900	13	-	-
U00J	800	12	-	-
U00K	700	11	40	50
U00L	900	13	50	50
U00M	1000	14	40	50
U00N	2800	29	100	140
U00O	3500	34	20	80
* U00P	>50000	450	1300	1500
U00Q	35000	170	400	720
U00R	1500	19	40	40
U00S	1000	14	-	-
V00J	800	12	-	-
V00K	900	13	40	40
V00L	1000	14	50	50
V00M	900	13	40	40
V00N	900	13	40	40
V00O	13000	85	500	500
V00P	4700	42	70	70
V00Q	12000	80	170	190
V00R	5000	44	100	100
V00S	700	11	-	-
W00K	800	12	-	-
W00L	800	12	30	30
W00M	800	12	30	30
W00N	900	13	40	50
W00O	1000	14	50	50
W00P	2100	120	600	800
W00Q	40000	190	900	1100
W00R	20000	115	140	170
W00S	1100	15	-	-
X00K	900	13	-	-
X00L	1100	15	-	-
X00M	1100	15	40	40
X00N	1000	14	40	40
X00O	1100	15	30	50
X00P	4000	37	120	160
X00Q	12000	80	300	400
* X00R	>50000	740	1900	2000
X00S	1500	19	-	-
Y00I	1000	14	-	-
Y00J	1300	17	-	-
Y00K	1600	20	-	-
Y00L	1600	20	-	-

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
Y00M	1100	15	40	40
Y00N	3000	30	30	50
Y00O	1700	20	40	50
Y00P	2100	24	40	60
Y00Q	9000	66	200	280
Y00R	40000	190	1000	1400
Y00S	3600	35	-	-
Z00I	800	10	40	40
Z00J	1000	14	40	50
Z00K	1800	21	70	90
Z00L	3200	32	80	80
Z00M	3700	35	120	150
Z00N	5000	44	110	130
Z00O	3300	32	80	120
Z00P	1900	22	50	60
Z00Q	2400	26	50	60
Z00R	12000	80	300	380
Z00S	2600	27	-	-
a00I	900	13	40	50
a00J	900	13	20	40
a00K	1300	17	50	90
a00L	1800	21	60	80
a00M	1900	22	120	140
a00N	1200	16	90	100
a00O	1300	17	40	40
a00P	1000	14	20	30
a00Q	2200	24	60	60
a00R	2300	25	70	100
a00S	2600	27	-	-
b00I	900	13	-	-
b00J	900	13	-	-
b00P	800	12	40	50
b00Q	700	11	30	70
b00R	2400	26	60	90
b00S	2400	26	-	-
c00N	700	11	-	-
c00O	700	11	40	40
c00P	1000	14	50	50
c00Q	1300	17	60	80
c00R	1900	22	50	80
c00S	1800	21	-	-
d00O	1400	18	40	60
d00P			30	50
d00Q			30	60
d00R	2000	23	60	70
d00S	2000	23	-	-
d00T	900	13	-	-

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count R ate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
d00U	1800	21	-	-
d00V	2200	24	50	50
d00W	2500	27	100	100
d00X	700	11	30	30
e00L	600	10	70	70
e00O	1700	14	-	-
e95O	1000	14	-	-
e00P	-	-	70	100
e95Q	1000	14	40	40
e95R	1300	17	40	80
e95S	1800	21	-	-
e95T	2500	27	-	-
e95U	3500	34	-	-
e95V	3400	33	100	100
e95W	4000	37	120	140
e95X	3000	30	100	100
e95Y	1500	19	50	60
e95Z	1700	20	70	80
e00a	2300	25	90	100
f00K	600	10	60	60
f00L	700	11	50	80
f00O	1100	15	40	60
f57Q	3400	33	-	-
f00R	2700	28	60	60
f00S	2700	28	-	-
f00T	4500	41	-	-
f00U	6000	50	-	-
f00V	50000	230	1060	1080
f00W	6000	50	120	140
f00X	6000	50	100	100
f00Y	1500	19	50	60
f00Z	1000	14	40	40
f00a	1000	14	30	50
f00M	-	-	60	60
g00K	700	11	50	50
g00L	600	10	80	90
g00M	600	10	60	90
g00O	2000	23	80	110
g00P	2000	23	50	90
g00Q	3300	32	70	100
g00R	21000	120	300	420
g00S	8000	62	-	-
g00T	6000	50	-	-
g00U	15000	95	-	-
g00V	11000	77	180	260
g00W	7000	56	110	140
g00X	2500	27	50	60

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
g00Y	2200	24	90	120
g00Z	1500	19	50	70
g00a	1000	14	30	30
h00K	700	11	30	30
h00L	800	12	70	70
h00M	900	13	70	80
h00N	1000	14	-	-
h00O	3100	31	70	70
h00P	17000	105	180	280
* h00Q	>50000	1050	4200	4200
h00R	27000	140	560	660
h00S	45000	205	900	1080
h00T	4000	37	150	150
h00U	6500	52	170	190
h00V	10000	72	240	250
h00W	3800	36	200	300
h00X	1000	14	60	80
h00Y	1800	21	50	50
h00Z	700	11	20	30
h00a	700	11	40	40
h72P	-	-	8000	9400
i00K	800	12	40	50
i00L	900	13	60	60
i00M	1700	20	90	110
i00N	8000	60	110	110
i00O	36000	175	1000	1100
* i00P	>50000	1600	7200	8400
* i00Q	>50000	1170	2800	3600
i00R	30000	155	900	1120
i00S	800	60	180	300
i00T	1600	20	40	40
i00U	3000	30	130	180
i00V	2200	24	-	-
i00W	1400	18	40	60
i00X	1000	14	40	60
i00Y	1500	19	70	70
j00K	800	12	60	60
j00L	900	13	60	80
j00M	2000	23	90	90
j00N	6000	49	130	160
j00O	10000	70	130	180
j00P	20000	115	400	420
j00Q	16000	98	410	500
j00R	21000	120	560	700
j00S	1900	22	70	90
j00T	1200	16	50	60
j00U	1000	14	60	60

Table 2, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate w/window (c/min)	Beta-Gamma Count Rate w/o window (c/min)
j00V	1800	21	70	70
j00W	1200	16	70	80
j00X	1000	14	50	50
j00Y	1100	15	60	60
k00L	1000	14	70	70
k00M	1100	15	90	110
k00N	1000	14	60	90
k00O	1000	14	70	90
k00P	1100	15	80	110
k00Q	1400	18	40	40
k00R	7500	58	140	180
k00S	1100	15	50	50
k00T	1100	15	30	50
k00U	1700	20	60	60
k00V	1700	20	50	60
k00W	700	11	40	40
k00X	700	11	40	50
k00Y	1000	14	40	50
l00L	900	13	70	70
l00M	900	13	70	80
l00N	800	12	70	70
l00O	900	13	80	90
l00P	700	11	60	70
l00Q	900	13	50	50
l00R	800	12	40	40
l00S	1200	16	40	50
l00T	1200	16	60	70
l00U	1100	15	60	80
l00V	900	13	30	40
m00O	800	12	80	80
m00P	700	11	60	60
m00Q	700	11	40	40
m00R	900	13	30	50
m00S	1000	14	40	40

* Reading >50,000 on NaI, reading was made with end window GM tube with beta shield.

Table 3

Surface Soil Sample Radionuclide Concentrations
(pCi/g), by Gamma Analysis

Location	Sample	K-40	U-238	Ra-226	Pb-214	Bi-214	Ra-223	Rn-219	Pb-211	Pb-212
G00C	Area 2, Berm	2.4E1	-----	2.1E0	2.1E0	2.1E0	-----	-----	-----	-----
i00Q	Area 2, Near Shuman Bld	-----	3.0E2	8.6E2	9.6E2	7.6E2	1.6E2	3.1E2	3.6E2	-----
Z00N	Area 2, Road Surface	-----	4.4E1	6.0E2	6.6E2	5.4E2	2.0E1	2.0E1	-----	-----
O00J	Area 2, Near Berm	-----	5.7E2	2.3E3	2.5E3	2.0E3	6.0E2	7.8E2	9.6E2	-----
O00G	Area 2, Near Berm	2.1E1	-----	1.0E1	1.1E1	9.6E0	-----	-----	-----	-----
N00I	Area 2, Near Berm	-----	5.5E2	2.0E3	2.0E3	2.1E3	4.9E2	7.9E2	8.9E2	-----
M00E	Area 2, Berm	1.3E1	-----	3.9E1	4.2E1	3.6E0	-----	-----	-----	-----
F00C	Area 2, Berm	1.4E1	-----	1.7E0	1.9E0	1.5E0	-----	-----	-----	-----
S00K	Area 2, Near Gravel Pile	3.2E1	-----	3.9E0	3.9E0	-----	-----	-----	-----	-----
i00P	Area 2, Near Shuman Bldg	-----	8.3E2	4.0E3	4.4E3	3.6E3	9.6E2	9.6E2	1.5E3	-----
S00L	Area 2, Near Gravel Pile	2.8E1	-----	2.5E0	2.4E0	2.6E0	-----	-----	-----	-----
h00Q	Area 2, Near Shuman Bldg	-----	1.5E2	3.0E1	3.4E2	2.6E2	1.7E2	1.9E2	1.5E2	-----
SPEC	Off-site Bkg Earth City	2.6E1	-----	2.5E0	2.5E0	2.5E0	-----	-----	-----	-----
i00P	Area 2, Duplicate	-----	6.4E2	2.7E3	3.0E3	2.4E3	2.3E3	1.2E3	1.1E3	-----
SPEC	Off-site Bkg Earth City	1.9E1	-----	2.7E0	2.5E0	2.9E0	-----	-----	-----	-----
Z00O	Area 2, Road Surface	-----	2.8E1	5.2E1	5.7E1	4.8E1	3.1E1	3.1E1	3.4E1	-----
SPEC	Leachate Treatment Sludge	-----	-----	6.9E0	7.9E0	5.9E0	-----	-----	-----	-----
N00I	Area 2, Near Berm	-----	7.6E2	7.1E3	1.0E4	4.2E3	2.2E3	2.0E3	1.8E3	-----
SPEC	Area 1, Base 6 Near Road	-----	6.5E2	2.4E3	2.7E3	2.1E3	1.6E3	1.4E3	1.0E3	-----
P00I	Area 2, Near Berm	1.7E1	1.0E0	7.0E0	7.3E0	6.8E0	-----	-----	-----	-----
SPEC	Area 1, Base 7 Near Road	-----	3.7E1	2.7E2	3.4E2	2.1E2	2.9E1	-----	5.8E1	2.2E0
SPEC	Leachate Treatment Sludge	-----	-----	2.3E0	-----	2.3E0	-----	-----	-----	-----
SPEC	Area 1, Base 6 Near Road	-----	6.5E2	2.7E3	3.1E3	2.5E3	1.2E3	1.1E3	9.5E2	-----
SPEC	Area 1, Base 5 Brown Soil	-----	3.9E2	1.1E3	1.6E3	8.2E2	2.8E2	3.8E2	3.7E2	-----
SPEC	Area 1, Base 5 Black Soil	-----	3.1E2	6.8E2	7.8E2	5.8E2	3.1E2	3.2E2	3.2E2	-----
SPEC	Off-site Bkg Taussig Road	3.2E1	-----	2.5E0	2.4E0	2.6E0	-----	-----	-----	2.4E0
SPEC	Area 1, Base 5 White Soil	-----	2.1E3	2.1E4	2.3E4	1.9E4	5.3E3	5.3E3	5.0E3	-----
i00P	Area 2, Duplicate	-----	6.2E2	3.5E3	3.7E3	3.2E3	1.3E3	1.3E3	1.7E3	-----
J00G	Area 1, Hot Spot	-----	3.4E1	9.7E1	1.1E2	8.3E1	4.3E1	4.3E1	4.6E1	-----
M00H	Area 1, Low Level Area	2.2E1	-----	2.7E0	2.6E0	2.8E0	-----	-----	-----	3.0E0
K00F	Area 1	2.0E1	-----	3.7E0	3.6E0	3.8E0	-----	-----	-----	2.1E0
SPEC	Area 1, East Berm	2.4E1	-----	2.6E0	2.2E0	2.9E0	-----	-----	-----	-----

Table 3 cont.

Location	Sample	K-40	U-238	Ra-226	Pb-214	Bi-214	Ra-223	Rn-219	Pb-211	Pb-212
I00L	Area 1	-----	-----	2.9E0	3.2E0	2.6E0	-----	-----	-----	2.3E0
SPEC	Area 1, East Berm	1.8E1	-----	2.4E0	2.2E0	2.6E0	-----	-----	-----	-----
P00H	Area 1, Near Road	3.0E1	-----	4.3E0	5.2E0	3.3E0	-----	-----	-----	1.8E0
N62H	Area 1	2.5E1	-----	4.1E0	3.4E0	4.7E0	-----	-----	-----	3.0E0
O11J	Area 1, Near Berm	-----	9.4E2	4.2E3	4.6E3	3.9E3	2.0E3	2.1E3	2.1E3	-----
L73E	Area 2, Side of Hill	-----	3.8E2	1.1E3	1.2E3	1.0E3	4.5E2	4.6E2	3.8E2	-----
K00F	Area 1	3.9E1	-----	4.4E0	5.2E0	3.5E0	-----	-----	-----	-----
N62H	Area 1, Fill	2.7E1	-----	3.1E0	3.1E0	3.1E0	-----	-----	-----	1.3E0
N00F	Area 1, Fill	-----	-----	2.6E0	3.0E0	2.1E0	-----	-----	-----	2.6E0
J00G	Area 1, Fill	-----	-----	2.3E0	3.5E0	1.1E0	-----	-----	-----	1.5E0
K66E	Area 1, Near Parking Lot	-----	-----	1.5E1	1.7E1	1.3E1	-----	-----	-----	-----
I00I	Area 1, Fill	3.1E1	-----	3.8E0	-----	3.8E0	-----	-----	-----	1.6E0

Soil Radiochemical Analysis

Table 4

Bi-214 from Gamma Spectroscopy

Sample	Activity pCi/gm U-238 (All +/- 25%)	Activity pCi/gm Th-230 (All +/- 25%)	Activity pCi/gm Bi-214 (All +/- 25%)
Area 1 Surface (1980)	3.8	82	2.1
Area 1 Surface (1980)	12	597	25
Area 1 Borehole 1 (1980)	21	188	44
Area 2 Surface (1980)	175	6,095	1,488
Area 2 Surface (1980)	18	338	9.4
Base 5 Surface (1981)	101	178,000	19,000
Base 6 Surface (1981)	54	46,100	2,600
Borehole 11 (1981)	82	29,200	1,800
N11J Surface (1981)	127	27,200	2,000
O11J Surface (1981)	1.0	52,000	3,900

Auger Hole NaI Counts and IG Analysis

Table 5

Borehole #1

		Radionuclide Concentrations [pCi/g]							
Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
00	>50,000	1.6E1	1.6E2	1.7E2	1.6E2	------	------	------	-------
01	>50,000	7.5E2	6.5E2	9E2	1.7E2	------	------	1.4E2	-------
02	>50,000	2.2E4	2.4E4	1.9E4	------	------	------	4.2E3	-------
03	>50,000	4.0E3	3.0E3	4.8E3	------	1.1E3	------	2.1E2	-------
04	>50,000	1.3E3	1.2E3	1.4E3	9.3E1	------	------	------	-------
05	20,000	2.4E1	-------	2.4E1	------	------	8.0E0	------	-------
06	4,500	3.9E0	3.5E0	4.3E0	------	------	1.1E1	------	-------
08	2,200	2.3E0	2.3E0	2.2E0	------	------	1.4E1	------	7.2E-1
10	2,000	2.3E0	2.4E0	2.2E0	------	------	1.3E1	------	8.3E-1
12	1,500	1.9E0	2.2E0	1.6E0	------	------	1.3E1	------	-------
14	1,300	1.8E0	1.9E0	1.7E0	------	------	9.7E0	------	6.3E-1
16	800	1.3E0	1.2E0	1.3E0	------	------	1.0E1	------	3.9E-1
18	800	1.2E0	1.6E0	8.0E-1	------	------	3.3E0	------	3.0E-1
20	800	8.1E-1	7.4E-2	8.7E-1	------	------	1.0E1	------	3.2E-1
22	500	6.5E-1	4.0E-1	9.0E-1	------	------	2.5E0	------	-------
24	150	2.5E-1	2.8E-1	2.1E-1	------	------	1.5E0	------	-------
26	1,000	6.3E-1	7.2E-1	5.4E-1	------	------	6.3E0	------	3.1E-1
28	1,300	8.7E-1	8.4E-1	8.9E-1	------	------	1.2E1	------	5.7E-1
30	500	4.3E-1	-------	4.3E-1	------	------	3.0E0	------	2.1E-1
32	700	1.3E0	1.E0	1.2E0	------	------	6.1E0	------	4.2E-1
34	1,400	2.4E0	2.5E0	2.2E0	------	------	6.1E0	------	5.4E-1
36	1,800	1.4E0	1.5E0	1.2E0	------	------	1.2E1	------	-------

Borehole #3

		Radionuclide Concentrations [pCi/g]							
Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
00	>50,000	8.4E2	7.8E2	8.4E2	------	------	------	6.4E1	-------
01	>50,000	1.5E4	1.3E4	1.9E4	1.4E3	------	------	------	-------
02	>50,000	7.0E3	5.3E3	8.7E3	------	------	------	------	-------
03	1,400	2.3E1	1.4E1	3.2E1	------	------	1.2E1	------	-------
05	2,300	6.2E0	5.8E0	6.6E0	------	------	8.9E0	------	-------
07	3,000	4.7E0	4.9E0	4.4E0	------	------	6.9E0	------	-------
09	1,800	3.5E0	4.2E0	2.8E0	------	3.6E0	8.2E0	------	-------
11	1,000	1.8E0	2.1E0	1.5E0	------	------	4.1E0	------	-------
13	600	1.7E0	1.4E0	2.0E0	------	------	------	------	-------
15	1,800	4.5E0	4.6E0	4.4E0	------	4.7E0	4.2E0	------	-------

Table 5, cont.

Borehole #3, cont. — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
17	1,000	9.0E-1	1.1E0	7.3E-1	------	------	6.4E0	------	4.4E-1
19	500	2.9E-1	3.E-1	2.1E-1	------	------	2.2E0	------	-------
21	500	5.0E-1	7.E-1	2.2E-1	------	------	2.0E0	------	-------
23	700	1.0E0	1.1E0	8.7E-1	------	------	6.3E0	------	5.3E-1
25	600	3.3E-1	3.7E-1	2.9E-1	------	------	------	------	-------
27	900	9.7E-1	1.1E0	8.4E-1	------	------	6.5E0	------	5.4E-1
29	1,000	5.4E-1	4.8E-1	6.0E-1	------	------	7.6E0	------	-------

Borehole #4 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	>50,000	------	1.5E2	1.7E2	1.3E2	9.5E1	------	9.9E1	-------
01	>50,000	5.3E2	2.1E3	1.7E3	2.5E3	9.8E2	------	1.2E3	-------
02	>50,000	------	1.2E2	9.E1	1.5E2	------	3.6E0	------	-------
03	14,000	------	2.8E0	2.1E0	3.5E0	------	3.8E0	------	-------
04	2,900	------	1.6E0	1.6E0	1.6E0	------	3.6E0	------	-------
06	1,100	------	1.4E0	1.5E0	1.2E0	8.6E-1	4.1E0	------	-------
08	1,200	------	1.7E0	1.9E0	1.5E0	9.0E-1	7.1E0	------	-------
10	1,500	------	2.7E	2.8E0	2.5E0	8.3E-1	9.3E0	3.8E0	-------
12	2,600	------	-------	------	------	------	------	------	-------
14	1,500	------	1.7E0	1.6E0	1.7E0	7.0E-1	7.0E0	------	-------
16	1,400	------	1.0E0	1.2E0	8.4E-1	------	------	------	-------
18	1,100	------	8.0E-1	8.E1-1	8.0E-1	------	8.5E0	------	3.8E-1
20	800	------	7.6E-1	8.6E-1	6.6E-1	------	------	------	-------
22	1,100	------	1.1E0	.1E0	1.1E0	------	7.7E0	------	4.1E1
24	1,200	------	7.5E-1	8.1E-1	7.0E-1	------	1.6E-1	------	3.5E-1
26	1,000	------	4.8E-1	4.2E-1	5.4E-1	------	6.6E0	------	3.0E-1
28	700	------	7.1E-1	7.2E-1	7.0E-1	------	------	------	-------
30	1,300	------	8.7E-1	9.9E-1	7.5E-1	------	1.4E1	------	6.4E-1
32	1,500	------	9.5E-1	9.5E-1	9.5E-1	------	1.5E1	------	-------
34	1,700	------	1.9E0	2.2E0	1.6E0	------	1.3E1	------	5.5E-1

Borehole #5 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
00	1,800	1.8E0	-------	1.7E0	------	------	6.3E0	------	-------
02	1,500	2.5E0	2.9E0	2.0E0	------	3.4E0	4.0E0	------	-------
04	2,700	3.4E0	3.7E0	3.1E0	------	------	4.4E0	------	-------
06	1,600	1.7E0	1.5E0	1.9E0	------	------	1.1E1	------	9.2E-1

Table 5, cont.

Borehole #5, cont. — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
08	1,000	1.3E0	1.6E0	1.0E0	------	------	1.0E1	------	-------
10	3,000	4.3E0	4.3E0	4.3E0	------	------	4.7E0	------	2.0E0
12	1,700	2.1E0	1.9E0	2.3E0	------	------	2.9E0	2.2E0	-------
14	1,000	1.8E0	1.3E0	2.3E0	------	------	3.0E0	------	-------
16	700	8.3E-1	6.0E-1	1.1E0	------	------	2.1E0	------	-------
18	500	8.9E-1	6.8E-1	1.1E0	------	------	2.1E0	------	-------

Borehole #6 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	2,000	------	7.3E0	8.3E0	6.4E0	7.4E0	9.4E0	1.2E1	-------
02	2,000	------	-------	------	------	------	------	------	-------
04	3,200	2.2E1	2.5E0	3.0E1	.0E1	2.0E1	------	1.9E1	-------
06	3,500	------	2.1E0	2.2E1	2.1E1	1.9E1	------	1.6E1	-------
07	6,000	1.6E1	1.5E1	1.7E1	1.3E1	8.1E0	------	------	-------
08	26,000	3.9E1	2.1E1	2.2E1	2.1E1	1.8E1	------	1.5E1	-------
09	>50,000	------	4.0E1	4.1E1	4.0E1	3.6E1	------	------	-------
10	43,000	------	5.8E1	5.3E1	6.3E1	4.1E1	------	4.01E	-------
11	>50,000	------	3.6E2	2.8E2	2.3E2	2.0E2	------	1.7E2	-------
12	16,000	4.4E1	9.9E1	9.1E1	1.1E2	3.9E1	------	5.6E1	-------
13	2,600	------	6.4E0	7.2E0	5.5E0	4.4E0	8.5E0	------	-------
15	1,100	------	-------	------	------	------	------	------	-------

Borehole #8 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	2,000	------	3.7E0	4.0E0	3.4E0	1.5E0	5.2E0	------	4.9E-1
02	1,500	------	1.4E0	1.5E0	1.3E0	------	6.5E0	------	-------
04	1,100	------	1.1E0	1.2E0	9.2E-1	------	4.7E0	------	-------
06	1,400	------	1.1E0	1.1E0	1.1E0	------	1.1E1	------	8.3E-1
08	1,400	------	1.1E0	1.1E0	1.1E0	------	1.1E1	------	8.E-1
10	1,500	------	1.2E0	1.2E0	1.1E0	------	1.1E1	------	-------
12	1,400	------	1,2E0	1.1E0	1.3E0	------	1.3E1	------	7.E-1
14	1,600	------	1.1E0	1.1E0	1.1E0	------	1.5E1	------	-------
16	1,000	------	1.1E0	1.3E0	8.2E-1	------	1.1E1	------	-------
18	1,400	------	1.2E0	1.4E	1.1E0	------	1.4E1	------	4.7E-1
20	1,700	------	1.8E0	2.0E0	1.6E0	1.1E0	------	------	8.4E-1

Table 5, cont.

Borehole #9 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	1,400	------	2.2E0	2.3E0	2.0E0	------	------	------	3.2E-1
02	22,000	4.6E1	5.6E1	5.6E1	5.5E1	3.5E1	1.1E1	3.1E1	-------
03	11,000	------	5.4E0	4.2E0	6.5E0	------	1.2E1	------	-------
04	2,000	------	1.3E0	1.3E0	1.4E0	------	9.3E0	------	-------
06	600	------	7.0E-1	8.4E-1	5.6E-1	------	3.8E0	------	-------
08	1,000	------	9.8E-1	7.8E-1	1.2E0	------	6.1E0	------	-------
10	900	------	8.0E-1	9.5E-1	6.5E-1	------	5.E0	1.6E0	-------
12	1,000	------	1.1E0	1.3E0	1.0E0	------	8.1E0	------	3.4E-1
14	700	2.7E0	7.7E1	8.3E-1	7.0E-1	------	4.9E0	------	5.0E-1
16	1,100	------	1.0E0	1.0E0	1.0E0	------	------	------	4.7E-1
18	1,300	------	-------	------	------	------	------	------	-------
20	1,000	7.6E-1	1.1E0	1.2E0	9.8E-1	------	8.7E0	------	-------
22	1,200	------	1.3E0	1.3E0	1.2E	------	9.5E0	------	5.3E-1

Borehole #10 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	7,000	------	3.5E0	3.3E0	3.7E0	9.4E-1	3.6E0	------	-------
01	35,000	------	1.4E1	9.2E0	1.8E1	4.4E0	3.6E0	------	-------
02	>50,000	------	4.2E2	3.7E2	4.8E2	------	------	------	-------
03	>50,000	------	4.8E2	4.4E2	5.2E2	------	------	------	-------
04	35,000	------	2.5E1	1.8E1	3.E1	------	------	------	-------
05	13,000	------	9.4E0	8.3E0	1.E1	------	------	------	-------
06	4,500	------	1.2E1	1.4E1	1.0E1	3.9E0	------	5.0E0	3.1E-1
08	2,000	------	1.3E1	1.1E1	1.5E1	------	------	------	2.4E-1
10	1,800	7.3E1	1.2E2	1.3E2	1.0E2	7.0E1	------	4.5E1	-------
12	2,000	1.2E1	1.6E1	1.8E1	1.3E1	1.1E1	4.2E0	1.1E1	-------
14	500	4.9E0	5.1E0	6.1E0	4.0E0	2.7E0	3.0E0	------	-------

Borehole #11 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
00	>50,000	8.4E1	6.6E1	1.0E2	------	2.2E1	5.6E0	------	-------
01	>50,000	3.6E3	2.9E3	4.4E3	7.7E2	------	------	------	-------
02	>50,000	1.3E4	-------	1.3E4	2.9E3	------	------	------	-------
03	>50,000	1.7E3	1.1E3	.2E3	------	------	------	------	-------
04	30,000	7.0E0	5.3E0	8.6E0	------	------	------	------	-------
05	22,000	4.9E0	4.6E0	5.2E0	------	3.6E0	1.3E1	7.1E0	7.4E0

Table 5, cont.

Borehole #11, cont. — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	Ra-226	Pb-214	Bi-214	U-238	Ra-223	K-40	Pb-211	Pb-212
06	20,000	7.1E0	7.4E0	6.7E0	------	4.6E0	1.5E1	------	
07	20,000	8.3E0	8.8E0	7.8E0	------	------	1.1E1	------	
08	20,000	1.3E1	1.5E1	1.2E1	------	2.0E1	1.0E1	5.8E0	-------
09	20,000	------	-------	------	------	------	------	------	-------

Borehole #16 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
02	6,000	1.3E1	1.4E1	1.6E1	1.1E1	4.3E0	6.2E0	6.1E0	-------
03	9,000	------	1.8E1	2.2E1	1.5E1	6.9E0	7.9E0	8.8E0	-------
04	33,000	2.8E1	5.0E1	5.9E1	4.2E1	2.0E1	5.0E0	1.6E1	-------
05	48,000	6.5E1	1.1E2	1.3E2	9.8E1	5.6E1	1.0E1	3.7E1	-------
06	35,000	------	1.2E2	1.4E2	1.0E2	7.8E1	6.7E0	4.3E1	-------
07	9,000	------	4.8E1	5.5E1	3.1E1	3.1E1	------	2.0E1	8.2E-1
08	6,000	1.2E1	1.4E1	1.5E1	1.2E1	4.8E0	3.7E0	------	-------
09	15,000	------	1.5E1	1.7E1	1.3E1	7.0E0	4.1E0	5.5E0	-------
10	35,000	------	5.8E1	6.6E1	5.0E1	7.5E1	2.3E0	2.5E1	-------
11	>50,000	1.7E2	3.8E2	4.5E2	3.1E2	1.7E2	------	1.4E2	8.5E-1
12	>50,000	1.9E2	5.1E2	6.0E2	4.8E2	3.0E2	------	1.4E2	2.8E0
13	>50,000	1.2E2	2.4E2	2.4E2	2.4E2	7.2E1	------	2.6E1	-------
14	>50,000	3.3E2	5.4E2	4.7E2	6.0E	2.4E2	------	4.0E2	-------
15	>50,000	------	9.2E3	6.9E3	1.1E4	------	------	------	-------
16	>50,000	------	7.7E3	6.1E3	9.2E3	------	------	------	-------
17	37,000	------	8.2E1	8.1E1	8.3E1	1.6E1	5.7E0	2.6E1	-------
18	8,000	------	2.9E1	3.0E1	2.7E1	6.1E0	------	1.5E1	-------
19	6,000	1.3E1	3.4E1	4.2E1	2.6E1	1.5E2	------	1.9E1	-------

Borehole #17 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	700	------	1.2E0	1.1E0	1.2E0	------	4.4E0	------	-------
02	600	------	5.4E-1	5.3E-1	5.4E-1	------	2.3E0	------	1.3E-1
04	300	------	3.3E-1	3.7E-1	2.9E-1	------	1.8E0	------	1.8E-1
06	250	------	2.6E-1	2.4E-1	2.7E-1	------	1.9E0	------	-------
08	300	------	2.4E-1	2.9E-1	1.9E-1	------	------	------	-------
10	300	------	2.9E-1	3.6E-1	2.2E-1	------	2.0E0	------	-------
12	400	------	2.7E-1	------	2.7E-1	------	3.0E0	------	2.1E-1
14	700	------	5.9E-1	5.3E-1	6.5E-1	------	4.7E0	------	6.5E-1

Table 5, cont.

Borehole #17, cont. — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
16	1,500	------	1.2E0	------	1.2E0	------	1.E1	------	-------
18	800	------	1.5E0	1.5E0	1.4E0	------	5.3E0	------	-------
20	3,000	------	8.5E0	9.0E0	8.0E0	2.9E0	6.5E0	------	-------
22	1,000	------	1.6E0	1.7E0	1.5E0	------	4.3E0	------	-------

Borehole #18 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	1,000	------	-------	------	------	------	------	------	-------
02	1,500	------	1.3E0	1.3E0	1.2E0	7.2E-1	7.8E0	------	-------
04	1,100	------	9.3E-1	1.0E0	8.3E-1	------	------	------	-------
06	1,000	------	9.9E-1	1.1E0	8.8E-1	------	6.90E	------	-------
08	600	------	4.1E-1	3.3E-1	4.8E-1	------	2.5E0	------	-------
10	600	------	5.7E-1	6.5E-1	4.9E-1	------	2.5E0	------	-------
12	1,100	------	7.7E-1	9.4E-1	6.1E-1	------	------	------	-------
14	1,000	------	6.7E-1	7.2E-1	6.1E-1	------	------	------	-------
16	1,000	------	7.6E-1	1.0E0	5.0E-1	------	------	------	4.8E-1
18	1,200	------	-------	------	------	------	------	------	-------

Borehole #19 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	1,000	------	1.3E0	1.4E0	1.3E0	------	1.6E0	------	-------
02	1,700	------	3.9E0	4.3E0	3.4E0	2.1E0	4.4E0	------	4.1E-1
04	2,100	------	3.9E0	4.2E0	3.5E0	------	1.4E1	------	8.1E-1
06	4,400	------	6.0E0	6.3E0	5.8E0	2.3E0	1.0E1	------	8.6E-1
07	28,000	3.3E1	3.7E1	3.5E1	3.9E1	2.2E1	1.3E1	2.5E1	-------
08	>50,000	4.2E1	3.4E2	3.4E2	3.4E2	2.3E2	7.5E0	2.3E2	-------
09	17,000	2.7E1	1.9E1	1.7E1	2.2E1	5.3E0	------	1.3E1	-------
10	4,600	------	4.2E0	3.9E0	4.4E0	------	6.1E0	------	-------
12	1,000	------	6.5E-1	6.0E-1	7.0E-1	------	4.9E0	------	-------
14	600	------	8.6E-1	1.1E0	6.4E-1	------	------	------	2.1E-1
16	500	------	6.4E-1	7.1E-1	5.7E-1	------	2.4E0	------	-------

Table 5, cont.

Borehole #20				Radionuclide Concentrations [pCi/g]					
Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	10,000	------	8.9E0	3.8E0	1.4E1	6.9E0	6.8E0	------	------
01	23,000	------	7.2E1	6.8E1	7.6E1	4.3E1	1.0E1	3.9E1	------
02	9,000	------	1.4E1	9.9E0	1.7E1	2.9E0	8.2E0	1.7E1	------
03	2,200	------	2.7E0	------	2.7E0	------	6.0E0	------	------
05	900	------	1.3E0	1.4E0	1.1E0	------	------	------	------
07	700	------	1.2E0	1.2E0	1.1E0	------	9.9E0	------	------
09	1,000	------	1.5E0	2.0E0	1.0E0	------	1.5E1	------	------
11	1,600	------	1.9E0	1.9E0	1.8E0	------	2.7E1	------	1.3E0
13	1,200	------	1.2E0	1.3E0	------	------	------	------	1.2E0
15	1,100	------	1.2E0	1.3E0	1.1E0	------	1.8E0	------	6.6E-1
17	500	------	7.0E-1	7.7E-1	6.4E-1	------	------	------	3.6E-1

Borehole #21				Radionuclide Concentrations [pCi/g]					
Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	14,000	2.1E1	3.4E1	4.2E1	2.7E1	------	------	------	------
01	13,000	------	1.3E1	1.3E1	1.2E1	3.2E0	1.8E0	------	------
02	1,300	------	1.2E0	9.5E-1	1.4E0	------	2.1E0	------	------
03	1,300	------	1.3E0	1.3E0	1.3E0	------	------	------	------
04	7,000	------	5.4E0	5.2E0	5.6E0	------	------	------	------
05	46,000	1.8E1	6.2E1	6.0E1	6.4E1	3.2E1	9.2E0	2.1E1	------
06	>50,000	1.7E1	6.6E2	5.4E2	7.8E2	------	------	3.3E2	------
07	>50,000	4.5E2	3.2E3	2.8E3	3.7E3	8.3E2	------	1.5E3	------
08	>50,000	3.2E1	7.3E1	6.7E1	7.9E1	2.9E1	------	3.2E1	------
09	32,000	------	3.6E1	3.6E1	3.5E1	9.3E0	8.2E0	1.2E1	------
10	9,000	------	2.2E1	2.8E1	2.0E1	1.9E0	5.6E0	------	------
11	4,300	------	1.5E1	1.7E1	1.2E1	------	3.3E0	------	------
12	6,000	------	5.8E0	6.2E0	5.4E0	------	5.9E0	------	------
13	7,000	------	8.1E0	8.8E0	7.3E0	3.8E0	1.1E1	------	8.5E-1
14	7,000	------	1.3E1	1.5E1	1.1E1	6.1E0	1.1E1	------	------
15	10,000	5.6E0	1.1E1	1.3E1	9.4E0	5.3E0	9.4E0	5.1E0	6.7E-1
16	8,000	------	6.5E0	7.2E0	5.7E0	3.2E0	4.4E0	------	------
17	,000	------	6.1E0	7.1E0	5.2E0	3.7E0	3.1E0	------	------
18	3,500	5.6E0	5.7E6	6.4E0	4.4E9	2.7E0	3.0E0	------	------
20	3,000	------	6.9E0	8.3E0	5.5E0	4.4E0	------	------	------

Table 5, cont.

Borehole #22				Radionuclide Concentrations [pCi/g]					
Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	10,000	------	2.4E1	2.7E1	2.1E1	1.6E1	2.7E0	------	-------
01	13,000	2.0E1	3.2E1	3.8E1	2.5E1	1.5E1	5.9E0	1.7E1	5.6E-1
02	11,000	1.9E1	2.8E1	3.2E1	2.5E1	1.6E1	4.1E0	1.5E1	-------
03	4,300	------	5.6E0	6.3E0	4.9E0	2.2E0	4.1E0	------	6.7E-1
04	5,500	------	1.1E1	1.2E1	8.8E0	5.9E0	6.5E0	------	-------
06	4,500	------	8.1E0	9.4E0	6.7E0	5.4E0	3.8E0	5.7E0	3.6E-1
07	5,000	9.4E0	8.9E0	1.0E1	7.3E0	5.4E0	6.3E0	------	7.0E-1
08	5,000	1.0E1	1.0E1	1.3E1	8.4E0	7.1E0	3.7E0	6.6E0	-------
10	4,300	------	1.5E1	1.8E1	1.2E1	7.3E0	2.8E0	5.E0	-------
12	7,000	------	1.4E1	1.7E1	1.1E1	------	4.1E0	------	-------
13	4,000	1.5E1	1.4E1	1.6E1	1.1E1	6.9E0	2.9E0	6.1E0	-------
14	7,000	9.1E0	1.3E1	1.6E1	1.1E1	4.7E0	4.8E0	------	-------
15	9,000	------	2.3E1	2.9E1	1.7E1	1.3E1	3.7E0	1.0E1	-------
16	8,000	------	2.3E1	2.8E1	1.9E1	1.6E1	2.0E0	1.1E1	-------
17	3,500	7.3E0	7.4E0	8.3E0	6.4E0	5.0E0	2.3E0	------	-------
18	7,000	1.8E1	1.8E1	2.0E1	1.5E1	6.1E0	------	------	-------
19	9,000	------	1.7E1	2.0E1	1.4E1	1.2E1	3.8E0	------	-------
20	13,000	------	3.5E1	4.0E1	3.0E1	2.5E1	3.7E0	1.5E1	-------
21	10,000	------	1.1E1	1.1E1	1.1E1	3.5E0	3.6E0	------	-------
22	24,000	------	1.9E1	1.6E1	2.1E1	4.1E0	4.3E0	6.3E0	-------
23	>50,000	------	5.8E3	5.8E3	5.8E3	3.0E2	------	2.6E2	-------
24	>50,000	------	7.0E2	6.4E2	7.5E2	2.9E2	------	3.3E2	-------
25	>50,000	------	6.4E2	6.4E2	6.4E2	3.6E2	------	3.4E2	-------

Borehole #31				Radionuclide Concentrations [pCi/g]					
Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	1,200	------	6.5E-1	5.6E-1	7.4E-1	------	7.8E0	------	5.6E-1
02	900	------	5.6E-1	5.9E-1	5.3E-1	------	------	------	4.5E-1
04	1,500	------	9.1E-1	9.3E-1	8.9E-1	------	6.5E0	1.7E0	-------
06	1,000	------	6.3E-1	6.4E-1	6.3E-1	------	6.1E0	------	-------
08	800	------	5.1E-1	4.5E-1	5.7E-1	------	------	------	-------
10	800	------	4.9E-1	5.2E-1	4.5E-1	------	------	------	3.8E-1
12	1,500	------	3.7E-1	3.7E-1	------	------	3.7E0	------	-------
14	1,100	------	7.1E-1	------	7.1E-1	------	1.3E1	------	-------
16	1,000	------	5.1E-1	------	5.1E-1	------	4.0E0	------	3.1E-1
18	1,500	8.5E-1	8.1E-1	8.6E-1	7.7E-1	------	8.1E0	------	8.0E-1

Table 5, cont.

Borehole #31, cont. — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
20	600	------	4.9E-1	4.8E-1	5.0E-1	------	------	------	6.2E-1
22	1,300	------	7.1E-1	8.4E-1	5.9E-1	------	------	------	-------
24	1,300	------	1.1E0	1.1E-1	1.0E0	------	6.2E0	------	-------

Borehole #32 — Radionuclide Concentrations [pCi/g]

Depth	Gross NaI	U-238	Pb-214	Bi-214	Ra-226	Ra-223	K-40	Pb-211	Pb-212
00	16,000	------	8.3E0	6.5E0	1.0E1	2.0E0	2.2E0	------	-------
01	>50,000	------	1.5E2	1.4E2	1.6E2	1.1E2	------	6.9E1	-------
02	17,000	------	4.9E1	4.1E1	5.7E1	2.0E1	3.9E0	1.9E1	-------
03	5,000	------	3.1E0	2.1E0	4.2E0	------	------	------	-------
04	1,300	------	3.1E0	2.1E0	4.2E0	------	------	------	-------
06	1,700	------	1.7E0	1.9E0	1.4E0	------	------	------	3.1E-1
08	1,700	------	1.9E0	2.2E0	1.6E0	------	8.2E0	------	3.8E-1
10	1,700	------	1.8E0	2.0E0	1.5E0	------	1.2E1	------	-------
12	1,600	------	1.6E0	1.7E0	1.5E0	------	1.2E1	------	6.0E-1
14	1,600	------	2.6E0	2.7E0	2.4E0	------	------	------	-------
16	1,800	------	1.7E0	1.5E0	1.9E0	------	------	------	7.1E-1
18	1,900	------	9.3E-1	8.7E-1	9.9E-1	------	1.4E1	------	8.5E-1

Auger Hole NaI (Tl) Counts

Table 5, cont.

Borehole #2		Borehole #7		Borehole #12	
Depth	NaI CPM	Depth	NaI CPM	Depth	NaI CPM
ft		ft		ft	
00	700	00	>50,000	00	1,000
01	1,300	01	>50,000	01	1,500
02	1,000	02	>50,000	02	1,300
03	1,000	03	23,000	03	2,000
04	1,400	04	7,000	04	3,000
05	1,000	05	3,600	05	3,500
06	1,400	06	1,300	06	1,500
07	1,400	07	1,000	07	1,000
08	1,300	08	1,000	08	800
09	1,200	09	1,100	09	700
10	1,000	10	1,000	10	700
11	700	11	1,100	11	500
12	800	12	1,200	12	500
13	800	13	1,400	13	350
14	1,200	14	1,200	14	350
15	3,500	15	1,200	15	500
16	11,000	16	1,400	16	350
17	2,500	17	1,500	17	900
18	1,400	18	1,700	18	900
19	1,000	19	1,700	19	1,000
20	1,000	20	4,000	20	1,500
21	800	21	2,200	21	1,500
22	1,000	22	2,000	22	1,300
23	800	--	-----	23	500
24	800	--	-----	24	600
25	800	--	-----	--	-----
26	1,500	--	-----	--	-----
26	1,500	--	-----	--	-----
27	1,000	--	-----	--	-----
28	800	--	-----	--	-----
29	600	--	-----	--	-----
30	600	--	-----	--	-----
31	500	--	-----	--	-----
32	700	--	-----	--	-----
33	1,000	--	-----	--	-----
34	1,000	--	-----	--	-----
35	1,000	--	-----	--	-----

Borehole #13		Borehole #23		Borehole #24	
00	900	00	1,100	--	-----
01	1,300	01	1,100	01	1,200
02	800	02	700	02	2,000
03	600	03	1,200	03	1,600
04	700	04	1,300	04	1,800
05	400	05	900	05	1,600
06	500	06	600	06	1,500

Table 5, cont.

Borehole #13 Depth	Borehole #13 NaI CPM	Borehole #23 Depth	Borehole #23 NaI CPM	Borehole #24 Depth	Borehole #24 NaI CPM
ft		ft		ft	
07	400	07	400	07	1,000
08	700	08	300	08	1,000
09	1,000	09	300	09	300
10	900	10	300	10	700
11	600	11	400	11	1,000
12	600	12	400	12	1,800
13	900	13	500	13	1,200
14	600	14	600	14	1,500
15	500	15	600	15	700
16	600	16	400	16	600
17	700	17	500	17	500
18	1,000	18	700	18	1,000
19	800	19	600	19	900
20	900	20	600	20	1,200
21	800	21	500	21	1,500
22	800	22	400	22	800
23	700	--	-----	23	500
24	900	--	-----	24	500

Borehole #25 Depth	Borehole #25 NaI CPM	Borehole #26 Depth	Borehole #26 NaI CPM	Borehole #27 Depth	Borehole #27 NaI CPM
00	1,200	--	-----	--	-----
01	1,900	01	1,600	01	1,300
02	1,800	02	2,500	02	1,800
03	2,600	03	2,600	03	1,200
04	2,400	04	3,500	04	1,200
05	2,200	05	19,000	05	1,300
06	12,000	06	10,000	06	600
07	19,000	07	2,100	07	700
08	5,000	08	1,300	08	300
09	1,900	09	800	09	300
10	1,700	10	500	10	600
11	800	11	500	11	700
12	1,100	12	500	12	700
13	800	13	600	13	600
14	500	14	500	14	1,000
15	700	15	600	15	1,300
16	800	16	1,100	16	800
17	500	17	800	17	900
18	500	18	600	18	500
19	700	19	900	19	400
20	400	20	1,200	20	500
21	400	21	1,000	21	500
22	400	22	1,200	22	700
23	400	23	900	23	1,000
24	900	24	600	24	1,000
25	1,000	25	500	--	-----
26	600	26	800	--	-----

Table 5, cont.

Borehole #25		Borehole #26		Borehole #27	
Depth	NaI CPM	Depth	NaI CPM	Depth	NaI CPM
ft		ft			
27	400	27	500	--	-----
28	500	28	500	--	-----
29	600	29	600	--	-----
30	700	30	500	--	-----
31	700	31	600	--	-----
32	1,000	32	700	--	-----
33	1,700	33	900	--	-----
34	1,100	34	600	--	-----
35	1,000	35	800	--	-----
36	1,600	36	1,500	--	-----
37	1,700	37	1,500	--	-----
38	1,100	38	1,000	--	-----
--	-----	39	1,000	--	-----

Borehole #28		Borehole #29		Borehole #30	
01	1,600	01	1,300	01	600
02	1,200	02	1,300	02	600
03	600	03	1,300	03	800
04	700	04	1,000	04	300
05	1,000	05	800	05	500
06	1,500	06	1,200	06	400
07	1,400	07	1,800	07	500
08	1,100	08	1,400	08	300
09	1,400	09	2,000	09	600
10	1,800	10	2,000	10	1,100
11	1,900	11	1,200	11	600
12	2,800	12	1,200	12	800
13	2,900	13	1,500	13	700
14	9,000	14	1,700	14	1,000
15	32,000	15	1,300	15	1,200
16	4,200	16	600	16	800
17	2,000	17	500	17	300
18	1,600	18	500	18	250
19	1,200	19	600	19	400
20	1,300	20	700	20	500
21	1,100	21	600	21	700
22	500	22	600	22	600
23	500	23	500	23	500
--	-----	--	-----	24	400
--	-----	--	-----	25	600
--	-----	--	-----	26	1,200
--	-----	--	-----	27	500
--	-----	--	-----	28	300
--	-----	--	-----	29	300
--	-----	--	-----	30	600
--	-----	--	-----	31	500
--	-----	--	-----	32	400
--	-----	--	-----	33	400

Table 5, cont.

Borehole #33		Borehole #34		Borehole #35	
Depth	NaI CPM	Depth	NaI CPM	Depth	NaI CPM
ft		ft		ft	
01	1,900	01	2,600	01	10,000
02	1,200	02	1,300	02	38,000
03	800	03	1,400	03	>50,000
04	700	04	1,000	04	>50,000
05	600	05	1,500	05	22,000
06	1,000	06	1,500	06	22,000
07	1,000	07	1,000	07	1,500
08	800	08	400	08	1,500
09	800	09	300	09	800
10	500	10	400	10	700
11	500	11	500	11	700
12	400	12	800	12	600
13	300	13	700	13	00
14	00	14	500	14	1,100
15	400	15	600	15	1,400
16	500	16	900	16	1,400
17	900	17	600	17	800
18	900	18	700	18	700
19	1,000	19	1,300	19	600
20	1,100	20	800	20	600
21	800	21	400	21	600
22	800	22	300	22	700
--	-----	23	300	--	-----

Borehole #36		Borehole #37		Borehole #38	
01	1,200	01	1,500	01	7.000
02	700	02	1,400	02	7,000
03	900	03	1,100	03	8,000
04	1,600	04	1,100	04	12,000
05	1,800	05	1,200	05	22,000
06	2,500	06	1,500	06	>50,000
07	5,000	07	1,700	07	>50,000
08	1,700	08	800	08	>50,000
09	1,000	09	800	09	>50,000
10	800	10	800	10	>50,000
11	900	11	1,000	11	>50,000
12	700	12	1,600	12	21,000
13	700	13	1,400	13	7,000
14	800	14	1,500	14	5,000
15	500	15	1,700	15	1,600
16	500	16	1,900	16	1,000
17	600	17	1,800	17	1,000
18	900	18	1,400	18	600
19	800	19	900	19	800
20	700	20	1,000	20	600
21	600	21	1,500	21	400
--	-----	22	600	22	700
--	-----	23	600	23	1,000
--	-----	24	500	--	-----

Table 5, cont.

Borehole #39		Borehole #40		Borehole #41	
Depth	NaI CPM	Depth	NaI CPM	Depth	NaI CPM
ft		ft		ft	
01	3,000	01	7,000	01	1,400
02	11,000	02	26,000	02	1,400
03	4,000	03	6,000	03	1,200
04	1,900	04	2,100	04	1,500
05	1,000	05	1,600	05	1,900
06	1,500	06	1,900	06	1,200
07	1,000	07	3,500	07	700
08	700	08	5,000	08	600
09	500	09	3,200	09	700
10	500	10	1,500	10	1,000
11	400	11	800	11	1,000
12	500	12	1,200	12	1,300
13	400	13	1,500	13	1,000
14	800	14	1,500	14	600
15	1,200	15	1,300	15	600
16	1,300	16	1,000	16	600
17	900	17	800	17	500
18	600	18	600	18	500
19	700	19	1,200	19	200
20	1,000	20	1,200	20	200
--	-----	21	1,300	21	300
--	-----	22	1,300	22	300
--	-----	--	-----	23	300
--	-----	--	-----	24	500

Water Sample Analysis Results

Table 6

Sample No.	Date	Location	Gross Alpha pCi/l		Gross Beta pCi/l	
7001	6/8/81	Surface Water North of Shuman Building	3.11E0	+/-8.8%	2.25E1	+/-3.0%
7002	6/9/81	Surface Water West of Shuman Building	8.00E0	+/-9.9%	2.34E1	+/-4.4%
7003	6/10/81	Drainage Pipe at NE Boundary	1.56E0	+/-22%	9.88E0	+/-6.8%
7004	6/11/81	Stream Beneath Earth City Expressway (offsite)	1.04E0	+/-14%	1.97E1	+/-4.8%
7009	6/29/81	Borehole #14	4.50E0	+/-39%	2.23E1	+/-14%
7010	6/29/81	Borehole #15	2.60E0	+/-52%	1.52E1	+/-17%
7011	6/18/81	Borehole #14	3.12E0	+/-47%	1.06E1	+/-20%
7012	6/18/81	Borehole #15	7.10E0	+/-31%	1.66E1	+/-16%
7013	6/3/81	Middle Leachate Treatment Lagoon	-1.04E0	+/-275%	1.30E2	+/-5.7%
7014	6/3/81	North Leachate Treatment Lagoon	1.35E0	+/-55%	1.36E2	+/-5.5%
7015	6/3/81	South Leachment Treatment Lagoon	2.43E0	+/-55%	1.03E2	+/-6.4%
7016	6/3/81	Sludge Drainage Pipe	-1.21E0	+/-234%	9.89E1	+/-6.5%
7017	7/10/81	Borehole #14	5.20E-1	+/-115%	3.36E1	+/-11%
7018	7/10/81	Borehole #15	6.76E0	+/-32%	3.61E1	+/-11%
7019	6/29/81	Surface Pond North of Entrance on St. Charles Rock Road	1.91E0	+/-60%	3.00E1	+/-12%
7020	6/17/81	Borehole #15	8.84E0	+/-28%	3.01E1	+/-12%
7021	7/20/81	Tap Water	1.56E0	+/-67%	2.91E1	+/-12%
7022	7/10/81	Middle Leachate Treatment Lagoon	3.45E0	+/-141%	1.07E2	+/----%
7023	7/10/81	North Leachate Treatment Lagoon	-2.95E0	+/-189%	1.22E2	+/-5.8%
7024	7/10/81	South Leachment Treatment Lagoon	-1.56E0	+/-179%	8.67E1	+/-6.9%
7025	7/21/81	Settling Pond at North Boundary of Site	1.56E0	+/-67%	3.65E1	+/-11%
7026	6/17/81	Borehole #14	-8.66E-1	+/-332%	3.89E1	+/-10%
7027	5/11/81	Standing Water at Earth City Background Site	1.04E0	+/-82%	3.25E1	+/-11%
7028	4/29/81	Standing Water at NW Corner of Shuman Building	4.52E1	+/-6.2%	8.78E1	+/-6.9%
7029	4/29/81	West Ditch Runoff	-2.08E0	+/-131%	-3.62E0	+/-137%
7030	7/28/81	Pond at North Boundary of Site	5.20E-1	+/-115%	3.51E1	+/-11%
7031	7/28/81	Surface Pond North of Entrance on St. Charles Rock Road	-1.39E0	+/-203%	2.63E1	+/-13%
7032	7/30/81	Missouri River Water	-2.6E0	+/-102%	2.63E1	+/-13%
7033	7/30/81	Missouri River Water	1.04E0	+/-82%	2.90E1	+/-12%
7034	7/28/81	North Leachate Treatment Lagoon	-1.39E0	+/-203%	1.03E2	+/-6.3%
7035	7/28/81	Middle Leachate Treatment Lagoon	1.04E0	+/-82%	8.45E1	+/-7.0%

Table 6, cont.

ample No.	Date	Location	Gross Alpha pCi/l		Gross Beta pCi/l	
7036	7/28/81	South Leachate Treatment Lagoon	-2.95E0	+/-189%	6.96E1	+/-7.7%
1	11/80	Leachate Observation Well	7.3E0	+/-120%	8.0E1	+/-25%
2	10/80	Off-site Sample Well 3, West Boundary of Landfill	1.5E1	+/-17%	4.1E1	+/-10%
3	10/80	Off-site Sample Well 4, North Boundary of Landfill	2.9E0	+/-29%	7.6E0	+/-26%
4	11/80	Settling Pond North of Landfill	2.9E0	+/-150%	2.6E1	+/-110%

:mple No.	Date	Location	Isotopic Analysis K-40 pCi/l		Ra-226 pCi/l	
7014	6/3/81	North Leachate Treatment Lagoon	1.38E2	+/-15%	1.20E0	+/-21%
7015	6/3/81	South Leachate Treatment Lagoon	1.36E2	+/-16%	3.92E0	+/-233%
7016	6/3/81	Sludge Drainage Pipe	1.02E2	+/-15%	2.40E0	+/-290%
7022	7/10/81	Middle Leachate Treatment Lagoon	1.04E2	+/-18%	2.40E0	+/-290%
7028	4/29/81	Standing Water at NE Corner Shuman Bldg.	1.24E2	+/-28%	1.15E0	+/-195%

Radon Flux Measurements Using Accumulator Method

Table 7

Date	Time	Location	Environmental Conditions	Flux pCi/sq.m-s
04/21	09:33	Base 1 (Area 2, O11J)	10 degrees C, damp ground, moderate wind	28
04/21	10:21	Base 2 (Area 2, L38K)	10 degrees C, damp ground, moderate wind	6.7
04/22	11:48	Base 1 (Area 2, O11J)	15 degrees C, soaked ground, 1 hour after rain	332
04/22	12:38	Base 3 (Area 2, M99H)	15 degrees C, soaked ground, 1 hour after rain	1.7
04/23	08:24	Base 1 (Area 2, O11J)	15 degrees C, damp ground, sunny, last rain approx. 12 hours	293
04/23	09:12	Base 3 (Area 2, M99H)	15 degrees C, damp ground, sunny, last rain approx. 12 hours	7.9
04/23	10:00	Base 2 (Area 2, L38K)	15 degrees C, damp ground, sunny, last rain approx. 12 hours	5.9
04/24	08:38	Base 3 (Area 2, M99H)	7 degrees C, damp ground, cloudy, last rain approx. 2 days	2.7
04/24	08:40	Base 1 (Area 2, O11J)	7 degrees C, damp ground, cloudy, last rain approx. 2 days	9.8
04/24	09:29	Base 2 (Area 2, L38K)	7 degrees C, damp ground, cloudy, last rain approx. 2 days	1.5
04/27	09:05	Base 3 (Area 2, M99H)	21 degrees C, hot, ground dry, sunny	2.2
04/29	08:52	Base 3 (Area 2, M99H)	18 degrees C, sunny, last rain approx. 12 hours, light breeze	14
04/29	09:36	Base 1 (Area 2, O11J)	18 degrees C, sunny, last rain approx. 12 hours, light breeze	540
04/29	11:10	Base 4 (Area 2, i00P)	18 degrees C, sunny, last rain approx. 12 hours, light breeze	63
05/04	10:05	Base 1 (Area 2, O11J)	Cloudy, drizzle, last heavy rain approx. 1 day	43
05/04	15:34	Base 1 (Area 2, O11J)	Cloudy, drizzle, last heavy rain approx. 1 day	33
05/05	09:44	Base 1 (Area 2, O11J)	Cloudy, drizzle, soaked ground, no wind	177
05/06	09:49	Base 1 (Area 2, O11J)	7 degrees C, windy, wet ground, last rain approx. 12 hours	269
05/07	09:32	Base 1 (Area 2, O11J)	10 degrees C, windy, ground dry at surface, sunny	34
05/07	10:48	Base 3 (Area 2, M99H)	10 degrees C, windy, ground dry at surface, sunny	1.5
05/08	09:45	Base 3 (Area 2, M99H)	15 degrees C, cloudy, moderate wind, ground moist	8.5
05/08	10:28	Base 4, (Area 2, i00P)	15 degrees C, cloudy, moderate wind, ground moist	243
05/11	11:43	Base 4 (Area 2, i00P)	13 degrees C, light wind, soaked ground, rain approx. 12 hours ago	28

Table 7, cont.

Date	Time	Location	Environmental Conditions	Flux pCi/sq.m-s
05/12	11:15	Base 4 (Area 2, i00P)	15 degrees C, windy, cloudy, last rain approx. 1 day	310
05/12	12:08	Base 1 (Area 2, O11J)	15 degrees C, windy, cloudy, last rain approx. 1 day	18
05/13	10:10	Base 4 (Area 2, i00P)	13 degrees C, cloudy, ground moist, last rain approx. 8 hours	206
05/13	10:50	Base 1 (Area 2, O11J)	13 degrees C, cloudy, ground moist, last rain approx. 8 hours	30
05/14	10:30	Base 5 (Area 2,)	13 degrees C, cloudy, light wind, drizzle	43
05/14	11:04	Base 6 (Area 1, I00A)	13 degrees C, cloudy, light wind, drizzle	376
05/15	09:51	Base 6 (Area 1, I00A)	15 degrees C, sunny, light wind	380
05/18	10:13	Base 6 (Area 1, I00A)	10 degrees C, cloudy, heavy rain last 2 days, strong wind	188
05/19	09:44	Base 1 (Area 2, O11J)	10 degrees C, drizzle, ground soaked	8.0
05/19	10:24	Base 4 (Area 2, i00P)	10 degrees C, drizzle, ground soaked	17
05/19	10:24	Base 6 (Area 1, I00A)	10 degrees C, drizzle, ground soaked	538
05/20	10:01	Base 1 (Area 2, O11J)	18 degrees C, no wind, sunny, ground damp	276
05/20	10:41	Base 4 (Area 2, i00P)	18 degrees C, no wind, sunny ground damp	119
05/20	11:23	Base 6 (Area 1, I00A)	18 degrees C, no wind, sunny ground damp	353
05/21	09:53	Base 1 (Area 2, O11J)	21 degrees C, sunny, no wind, dry soil	212
05/21	10:27	Base 4 (Area 2, i00P)	21 degrees C, suny, no wind, dry soil	406
05/27	08:51	Base 6 (Area 1, I00A)	21 degrees C, sunny, light breeze, dry soil	350
05/27	09:33	Base 1 (Area 2, O11J)	21 degrees C, sunny, light breeze, dry soil	596
05/27	10:12	Base 4 (Area 2, i00P)	21 degrees C, sunnny, light breze, dry soil	865
05/28	08:43	Base 4 (Area 2, i00P)	28 degrees C, dry soil, last rain 2 days 29.90" hg	400
05/28	11:44	Base 4 (Area 2, i00P)	28 degrees C, dry soil, last rain 2 days 29,90" hg	397
05/29	09:14	Area 2, k00R	29 degrees C, damp soil, light wind	1.8
06/02	08:45	Base 6 (Area 1, I00A)	30 degrees C, dry soil, 29.90" hg	620
06/03	14:54	Base 4 (Area 2, i00P)	32 degrees C, slight wind, dry soil 29.85 hg	580
06/04	09:03	Base 1 (Area 2, O11J)	34 degrees C, light wind, dry soil	388
06/04	10:10	Area 2, I00F	39 degrees C, no wind, damp soil	0.6
06/08	11:37	Base 4 (Area 2, i00P)	33 degrees C, dry soil, moderate breeze	245
06/09	09:21	Base 4 (Area 2, i00P)	33 degrees C, dry soil, slight breeze	579
06/09	10:39	Base 8 (Area 1, I00I)	33 degrees C, dry soil, strong wind	3.0
06/10	11:17	Area 2, M62J	21 degrees C, dry soil, no wind 29.92"	1.3
06/11	10:16	Area 2, U00P	18 degrees C, dry soil, light breeze	38

Table 7, cont.

Date	Time	Location	Environmental Conditions	Flux
				pCi/sq.m-2
06/11	10:39	Area 2, T00P	18 degrees C, dry soil, light breeze	85
06/11	12:07	Area 2, h00X	18 degrees C, dry soil, light breeze	1.8
06/11	12:20	Area 2, j00W	18 degrees C, dry soil, light breeze	1.9
06/12	09:56	Area 2, U00P	26 degrees C, damp soil, light breeze 29.98" hg	14
06/12	10:08	Area 2, T00P	26 degrees C, damp soil, light breeze 29.98" hg	35
06/12	11:20	Area 2, h00X	26 degrees C, damp soil, light breeze 29,98" hg	0.6
06/12	11:30	Area 2, j00W	26 degrees C, damp soil, light breeze 29.98" hg	1.0
06/15	10:03	Area 2, I00L	29 degrees C, dry soil, gusty, 760.5mm hg	0.8
06/15	10:15	Area 2, J00L	29 degrees C, dry soil, gusty, 760.5mm hg	0.7
06/23	10:17	Earth City, offsite bkg	27 degrees C, damp soil, no wind 30.14 hg	0.5
06/23	13:50	Taussig Rd, offsite bkg	27 degrees C, damp soil, no wind 30.14 hg	1.5
06/29	10:03	Area 2m U00P	n/a	16
07/06	10:20	Base 4 (Area 2, i00P)	Damp soil, slight breeze	138
07/06	11:24	Taussig Rd, offsite bkg	Damp soil, slight breeze	0.3
07/08	14:00	Area 2, J30L	31 degrees C, dry soil, slight breeze, 30.20" hg	0.4
07/08	14:30	Area 2, H04O	31 degrees C, dry soil, slight brze, 30.20" hg	0.4
07/10	10:19	Taussig Rd, offsite bkg	Damp soil, started to rain during accumulation	0.3
07/10	10:09	Old St. Charles Rock Rd Bkg	Damp soil, started to rain during accumulation	1.0
07/16	10:49	Area 1, M10G	26 degrees C, damp soil, 29.96" hg	22
07/17	10:10	Area 1, M10G	25 degrees C, dry soil, no wind, 30.02" hg	14
07/20	10:25	Base 6 (Area 1, I00A)	30 degrees C, damp soil, mild wind, 29.86" hg	59
07/22	11:25	Old St. Charles Rock Rd Bkg	26 degrees C, damp soil, no wind 30.10" hg	<0.1
07/24	08:14	Area 1, M10G	24 degrees C, damp soil, light wind, 30.06" hg	15
07/24	08:31	Area 2, p07S	24 degrees C, damp soil, light wind, 30.05" hg	168
07/28	09:05	Area 2, p07S	23 degrees C, damp soil, mild wind, 30.06" hg	34
07/28	09:23	Area 1, M10G	23 degrees C, damp soil, mild wind, 30.06" hg	61
07/29	08:09	Base 8 (Area 1, I00I)	18 degrees C, damp soil, light wind, 30.21" hg	0.5
07/29	08:26	Area 2, p07S	18 degrees C, damp soil, light wind, 30.21" hg	173
07/29	10:04	Old St. Charles Rock Rd Bkg	21 degrees C, damp soil, light wind, 30.21" hg	0.3
07/29	10:50	Taussig Road offsite bkg	21 degrees C, damp soil, light wind, 30.21" hg	0.2
07/30	08:09	Area 2, p07S	23 degrees C, dry soil, sunny, light wind, 30.21" hg	38
07/30	08:16	Area 1, O00M	23 degrees C, dry soil, sunny, light wind, 30.21" hg	3.2
07/30	09:20	Old St. Charles Rock Rd Bkg	23 degrees C, dry soil, sunny, light wind, 30.21'hg	0.2
07/31	10:08	Area 1, O00M	24 degrees C, very dry soil, sunny, light wind, 30.25" hg	2.0

Table 7, cont.

Date	Time	Location	Environmental Conditions	Flux
				pCi/sq.m-2
07/31	10:13	Area 1, E00F	24 degrees C, very dry soil, sunny, light wind, 30.25" hg	0.5
08/03	10:11	Area 1, E00F	25 degrees C, dry soil, light wind, 29.94" hg	3.4
08/03	10:14	Area 1, O00M	25 degrees C, dry soil, light wind, 29.94" hg	0.4
08/04	09:05	Area 1, E00F	29 degrees C, dry soil, light wind, 30.04" hg	6.4
08/04	09:11	Area 1, O00M	29 degrees C, dry soil, light wind, 30.04" hg	0.5
08/05	09:21	Area 1, E00F	28 degrees C, dry soil, light wind, 30.07" hg	9.6
08/05	09:25	Area 1, O00M	28 degrees C, dry soil, light wind, 30.07" hg	9.6
08/06	08:35	Area 1, E00F	27 degrees C, dry soil, light wind, 30.01" hg	0.4
08/06	08:40	Area 1, M10G	27 degrees C, dry soil, light wind, 30.01" hg	5.1
08/07	09:08	Area 2, p07S	27 degrees C, dry soil, light wind, 30.01" hg	122
08/07	09:15	Base 8 (Area 1, I00I)	27 degrees C, dry soil, light wind, 30.01" hg	0.4
08/17	10:05	Area 2, I00F	20 degrees C, dry soil, light wind, 30.08" hg	0.6
08/17	10:10	Area 2, I00L	20 degrees C, dry soil, light wind, 30.08" hg	0.3
08/18	09:14	Area 2, I00L	18 degrees C, dry soil, no wind, 30.11" hg	<0.1
08/18	09:17	Area 2, I00F	18 degrees C, dry soil, no wind, 30.11" hg	0.5
08/19	09:34	Area 2, I00L	18 degrees C, dry soil, no wind, 30.11" hg	0.3
08/19	09:40	Area 2, I00F	18 degrees C, dry soil, no wind, 30.11" hg	0.4

Radon Flux Measurements Using the Charcoal Canister Method

Table 8

Date	Location	Sampling Time(sec)	Enviromental Conditions	Flux pCi/sq.m-s
06/02	Base 6 (Area 1, I00a)	6,000	30 degrees C, dry soil, 29.90" hg	362
06/03	Base 4 (Area 2, i00P)	4,980	32 degrees C, dry soil, light wind, 29.85" hg	29
06/03	Base 4 (Area 2, i00P)	1,200	32 degrees C, dry soil, light wind, 29.85" hg	613
06/04	Base 1 (Area 1, O11J)	7,200	34 degrees C, dry soil light wind	147
06/10	Base 8 (Area 2, I00I)	55,320	21 degrees C, dry soil, no wind, 29.92" hg	2.0
06/10	Area 2, M00I	18,000	21 degrees C, dry soil, no wind, 29.92" hg	2.3
06/11	Area 2, L00G	60,300	18 degrees C, dry soil, light breeze	163
06/11	Area 2, U00P	22,500	18 degrees C, dry soil, light breeze	44
06/18	Area 2, 100S	54,900	n/a	2.2
06/12	Area 2, T00P	17,640	26 degrees C, damp soil, light breeze, 29.98" hg	30
06/23	Earth City, offsite bkg	21,600	27 degrees C, damp soil, no wind, 30.14" hg	0.9
06/24	Taussig Road, offsite bkg	61,200	n/a	0.8
06/30	Area 2, p00J	55,320	n/a	8.7
06/30	Area 2, U00P	20,940	n/a	74
07/01	Old St. Charles Rd, bkg	20,040	n/a	0.8
07/06	Area 2, i00P	50,400	Damp soil, light breeze	178
07/08	Area 1, H25N	14,100	31 degrees C, dry soil, slight breeze, 30.20" hg	0.9
07/08	Area 2, J30L	50,140	31 degrees C, dry soil, slight breeze, 30.20" hg	0.3
07/10	Area 1, I00L	22,540	Damp soil, during rain	0.6
07/15	Old St. Charles Rock Rd, bkg	54,540	n/a	1.6
07/16	Area 1, M10G	22.380	26 degrees C, damp soil, 29.96" hg	24
07/17	Area 1, M10G	57,240	25 degrees C, dry soil, no wind, 30.20" hg	14
07/20	Base 6 (Area 1, I00A)	5,880	30 degrees C, damp soil, mild wind, 29.86" hg	13
07/22	Old St. Charles Rock Rd, bkg	68,640	26 degrees C, damp soil, no wind, 30.10" hg	0.3
07/23	Area 1, M10G	60,960	n/a	4.5
07/28	Area 1, M10G	61,560	23 degrees C, damp soil, 30.06" hg	9.1
07/28	Area 2, p04S	63,240	23 degrees C, damp soil, 30.06" hg	32
07/29	Area 1, I00I, Base 6	57,540	18 degrees C, damp soil, light wind, 30.21"hg	0.4
07/29	Area 1, O00I	57,960	18 degrees C, damp soil, light wind, 30.21" hg	1.3
07/30	Area 2, p04S	55,080	23 degrees C, dry soil, light wind, 30.21" hg	212
07/30	Area 1, O00M	56,820	23 degrees C, dry soil, light wind, 30.21" hg	7.6
07/31	Area 1, E00F	56,340	24 degrees C, very dry soil, light wind, 30.25" hg	0.4
07/31	Area 1, O00M	56,220	24 degrees C, very dry soil, light wind, 30.25" hg	5.2
08/05	Area 1, E00F	52,800	28 degrees C, dry soil, light wind, 30.07" hg	0.6

Side-By-Side Radon Flux Measurements,
Accumulator versus Charcoal Canister Methods

Table 9

Location	Date	Charcoal Canister pCi/sq.m-2	Accumulator pCi/sq.m-2
Base 6	6-2	400	740
Base 4	6-3	680	790
Base 1	6-4	170	370
Base 8	6-9	2.1	3.0
Base 3	6-10	2.4	1.3
Borehole 3	6-11	50	38
T00P(Area 2)	6-12	30	35
Earth City	6-23	0.9	<1
Taussig Road	6-24	0.8	1.5
Base 4	7-6	180	140
Borehole 2	7-8	<0.5	<1
M10G(Area 1)	7-16	22.2	22.3
M10G(Area 1)	7-17	13.4	14.0
Base 6	7-20	14.1	59.2
Old St. Charles Rd	7-22	0.3	<1
M10G(Area 1)	7-24	4.6	15.3
M10G(Area 1)	7-28	9.8	60.5
20' W of Borehole #20	7-28	36.4	34.3
Base 8	7-29	0.5	0.5
20' W of Borehole #20	7-30	218	38
000M(Area 1)	7-30	2.9	3
000M(Area 1)	7-31	5.8	0.2

Working Level (WL) and Long-Lived Gross Alpha Activity
on High Volume Air Samples

Table 10

Sample Duration: 10 min.
Flow Rate: 570 l/min.
Total Volume: 1.4E6 ml

Date/Time	Location	7 Day Activity uCi/cc	WL
8105010805	Outside Trailer	2.03E-13+/-122%	.0016
8105010819	Outside Trailer	2.66E-13+/-103%	.0015
8105010918	Base 3	0+/-211%	.0010
8105010931	Base 1	3.13E-13+/-93%	.0008
8105040942	Outside Trailer	4.69E-14+/-365%	.0010
8105041013	Base 1	1.09E-13+/-188%	.0009
8105041124	C00G	4.69E-14+/-365%	.0012
8105041150	Base 4	2.66E-13+/-103%	.0016
8105111034	Earth City Background	4.69E-14+/-365%	.0003
8105121046	Earth City Background	4.69E-14+/-365%	.0004
8105121402	Outside Trailer	0+/-211%	.0002
8105121447	Base 4	4.22E-13+/-78%	.0006
8105121504	Outside W-L Office Bldg	7.34E-13+/-57%	.0003
8105121528	Base 1	1.56E-13+/-145%	.0002
8105121551	T00P	4.69E-14+/-365%	.0003
8105131154	Z00N	4.69E-14+/-365%	.0010
8105151010	Base 6	2.03E-13+/-122%	.0003
8105151035	Base 7	1.09E-13+/-188%	.0002
8105181022	Base 6	2.03E-13+/-122%	.0003
8105201107	Base 4	2.66E-13+/-103%	.0004
8105201137	Base 6	2.66E-13+/-103%	.0004
8105270821	Inside Trailer	1.41E-12+/-40%	.0110
8105271040	Base 6	7.81E-13+/-55%	.0002
8106021429	000J	2.03E-13+/-122%	.0007
8106021450	h000	4.69E-14+/-365%	.0007
8106080957	Drilling Borehole #1	1.56E-13+/-146%	.0006
8106081335	Drilling Borehole #2	4.69E-14+/-365%	.0005
8106091015	Drilling Borehole #3	7.34E-13+/-57%	.0009
8106091318	Drilling Borehole #4	1.15E-11+/-14%	.0020
8106091350	Drilling Borehole #4	8.55E-12+/-16%	.0027

Table 10, cont.

Date/Time	Location	7 Day Activity	WL
		uCi/cc	
8106100945	Drilling Borehole #5	2.66E-13+/-103%	.0012
8106101231	Drilling Borehole #7	4.22E-13+/-78%	.0015
8106101411	Drilling Borehole #8	4.22E-13+/-78%	.0012
8106231028	Earth City Background	1.09E-13+/-188%	.0005
8106231146	Inside Shuman	1.98E-12+/-33%	.0011
8106231407	Taussig Rd Background	4.69E-14+/-365%	.0005
8106300931	Borehole #32	4.69E-14+/-365%	.0006
8107070919	Old St. Charles Rd Bkg	0+/-211%	.0017
8011130845	Area 1, Near Road	--------------	.017
8011131030	Area 1 Highest Ext. Level	--------------	.014
8011131445	Area 2 Highest Ext. Level	--------------	.019
8011131507	Area 2 Suspected Surface Mat.	--------------	.038
8011140735	Inside Shuman Building	--------------	.031

Date/Time	Location	Isotopic Activities U-238	Isotopic Activities Ra-226
Composite Sample	All Onsite Samples	9.1E-14+/-1%	4.3E-14+/-1%

Note: Individual sample sensitivities are low due to short sampling time. However, all gross alpha activities except two are less than the maximum permissible concentrations (MPCs) for U-238 or Ra-226, for unrestricted areas, as listed in Appendix B, Table II, of 10CFR20. (These MPCs are 3.0E-12 uCi/cc for either nuclide.) The two exceptions occurred when drilling through contaminated materials.

Gamma Analysis of High Volume Air Samples for Rn-219 Daughters (Pb-211)

Table 11

Date	Time	Location	---Sample Activity (uCi/cc) at--- 405 KeV (3.4% ab)	427 KeV (1.8% ab)	832 KeV (3.4% ab)	Average uCi/cc
6/3	14:21	Base 4 (Area 2, i00P)	2.3E-10	---------	2.5E-10	2.4E-10
6/4	8:31	Base 1 (Area 2, 000J)	5.7E-11	---------	---------	5.7E-11
6/4	12:30	Base 4	1.0E-9	8.9E-10	9.3E-10	9.5E-10
6/18	14:00	Base 4	5.6E-10	4.8E-10	4.6E-10	5.0E-10
6/29	12:23	Base 6 (Area 1, N00A)	9.0E-11	---------	1.3E-10	1.1E-10

Table 12: Priority Pollutant Analyses of Auger Hole and Leachate Sludge Samples

Results of Chemical Analyses of
West Lake Landfill
7 July 1981

Parameter	Units	WTP *	BH-2 *	BH-13 *	BH-25 *	BH-31 *	BH-35 *
Antimony	mg/kg	0.077	0.268	0.325	0.355	0.218	21.0
Arsenic	mg/kg	0.62	6.0	7.0	2.0	4.0	1.0
Beryllium	mg/kg	0.038	0.12	0.24	0.18	0.20	0.14
Cadmium	mg/kg	0.052	2.2	2.3	2.27	4.0	37.5
Chromium	mg/kg	1.41	40.9	34	7.0	26.2	215
Copper	mg/kg	0.459	1039	88	23.2	131.6	356
Cyanide	mg/kg	0.10	0.028	0.12	1.61	0.376	0.97
Lead	mg/kg	19.7	356	431	49.0	251.6	1490
Mercury	mg/kg	5	0.22	0.36	0.14	0.10	0.84
Nickel	mg/kg	3.00	2[illegible].0	45.1	11.3	4	218.0
Selenium	mg/kg	0.12	1.6	1.2	1.2	1.2	0.9
Silver	mg/kg	0.134	0.580	0.369	0.165	0.264	0.409
Thallium	mg/kg	14.0	10.0	2.0	<0.1	0.6	3.5
Zinc	mg/kg	41.4	246	270	180	89	2395

* WTP - Waste treatment plant leachate sludge
BH-2 - Auger hole 2, Area 2
BH-13 - Auger hole 13, Area 2
BH-25 - Auger hole 25, Area 1
BH-31 - Auger hole 31, Area 2
BH-35 - Auger hole 35, Area 2

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. W.T.P. (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #569 DATE ANALYSIS COMPLETED 16 July 1981

ACID COMPOUNDS

	µg/l
2,4,6-trichlorophenol	ND
o-chloro-m-cresol	ND
2-chlorophenol	ND
2,4-dichlorophenol	ND
2,4-dimethylphenol	ND
2-nitrophenol	ND
4-nitrophenol	*
2,4-dinitrophenol	*
4,6-dinitro-o-cresol	ND
pentachlorophenol	ND
phenol	8.1

ND - Less than 1 µg/l
* - Less than 25 µg/l
** - Less than 250 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. W.T.P. (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #569 DATA ANALYSIS COMPLETED 22 July 1981

BASE/NEUTRAL COMPOUNDS

	µg/l		µg/l
acenaphthene	ND	nitrobenzene	ND
benzidine	**	N-nitrosodimethylamine	**
1,2,4-trichlorobenzene	ND	N-nitrosodiphenylamine	**
hexachlorobenzene	ND	N-nitrosodi-n-propylamine	**
hexachloroethane	ND	bis(2-ethylhexyl)phthalate	*
bis(2-chloroethyl)ether	ND	butyl benzyl phthalate	ND
2-chloronaphthalene	ND	di-n-butyl phthalate	ND
1,2-dichlorobenzene	ND	di-n-octyl phthalate	ND
1,3-dichlorobenzene	ND	diethyl phthalate	ND
1,4-dichlorobenzene	ND	dimethyl phthalate	ND
3,3'-dichlorobenzidine	*	benzo(a)anthracene	ND
2,4-dinitrotoluene	**	benzo(a)pyrene	ND
2,6-dinitrotoluene	*	benzo(b)fluoranthene[1]	ND
1,2-diphenylhydrazine	ND	benzo(k)fluoranthene[1]	ND
fluoranthene	ND	chrysene	ND
4-chlorophenyl phenyl ether	ND	acenaphthylene	ND
4-bromophenyl phenyl ether	ND	anthracene	ND
bis(2-chloroisopropyl)ether	*	benzo (g.h.i.) perylene	*
bis(2-chloroethoxy)methane	ND	fluorene	ND
hexachlorobutadiene	ND	phenanthrene	ND
hexachlorocyclopentadiene	*	dibenzo (a,h)anthracene	*
isophorone	ND	indeno(1,2,3-c,d)pyrene	ND
naphthalene'	ND	pyrene	ND
bis(chloromethyl)ether	**	2,3,7,8-tetrachlorodibenzo-p-dioxin	**

ND - Less than 1 µg/l
* - Less than 10 µg/l
** - Less than 25 µg/l

[1]Benzo(b)fluoranthene and benzo(k)fluoranthene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. W.T.P. (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #569 DATE ANALYSIS COMPLETED 24 July 1981

PESTICIDES

	μg/l		μg/l
aldrin	ND	a-BHC	ND
dieldrin	ND	b-BHC	ND
chlordane	ND	d-BHC	*
4,4'-DDT	ND	g-BHC	ND
4,4'-DDE	ND	PCB - 1242	ND
4,4'-DDD	ND	PCB - 1254	ND
endosulfan I	*	PCB - 1221	ND
endosulfan II	*	PCB - 1232	ND
endosulfan sulfate	*	PCB - 1248	ND
endrin	*	PCB - 1260	ND
endrin aldehyde	*	PCB - 1016	ND
heptachlor	ND	toxaphene	ND
heptachlor epoxide	*		

ND - Less than 1 μg/l
* - Less than 10 μg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. W.T.P. (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #569 DATE ANALYSIS COMPLETED 5 August 1981

VOLATILES

	μg/l		μg/l
acrolein	**	1,2-dichloropropane	ND
acrylonitrile	**	1,3-dichloropropylene[1]	*
benzene	2.0	ethylbenzene	ND
carbon tetrachloride	*	methylene chloride	15.6
chlorobenzene	ND	methyl chloride	*
1,2-dichloroethane	ND	methyl bromide	*
1,1,1-trichloroethane	ND	bromoform	ND
1,1-dichloroethane	ND	dichlorobromomethane	ND
1,1,2-trichloroethane	ND	trichlorofluoromethane	2.3
1,1,2,2-tetrachloroethane	ND	dichlorodifluoromethane	*
chloroethane	*	chlorodibromomethane	ND
2-chloroethylvinyl ether	*	tetrachloroethylene	ND
chloroform	4.3	toluene	1.8
1,1-dichloroethylene	ND	trichloroethylene	ND
1,2-trans-dichloroethylene	*	vinyl chloride	*

ND - Less than 1 μg/l
 * - Less than 10 μg/l
** - Less than 100 μg/l

[1] 1,3-cis-dichloropropylene and 1,3-trans-dichloropropylene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-2 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #570 DATE ANALYSIS COMPLETED 16 July 1981

ACID COMPOUNDS

	µg/l
2,4,6-trichlorophenol	ND
o-chloro-m-cresol	ND
2-chlorophenol	ND
2,4-dichlorophenol	ND
2,4-dimethylphenol	ND
2-nitrophenol	ND
4-nitrophenol	*
2,4-dinitrophenol	*
4,6-dinitro-o-cresol	ND
pentachlorophenol	ND
phenol	7.8

ND - Less than 1 µg/l
* - Less than 25 µg/l
** - Less than 250 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-2 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #570 DATA ANALYSIS COMPLETED 22 July 1981

BASE/NEUTRAL COMPOUNDS

	µg/l	
acenaphthene	ND	nitrobenzene
benzidine	**	N-nitrosodimethylamine
1,2,4-trichlorobenzene	ND	N-nitrosodiphenylamine
hexachlorobenzene	ND	N-nitrosodi-n-propylamine
hexachloroethane	ND	bis(2-ethylhexyl)phthalate
bis(2-chloroethyl)ether	ND	butyl benzyl phthalate
2-chloronaphthalene	ND	di-n-butyl phthalate
1,2-dichlorobenzene	ND	di-n-octyl phthalate
1,3-dichlorobenzene	ND	diethyl phthalate
1,4-dichlorobenzene	ND	dimethyl phthalate
3,3'-dichlorobenzidine	*	benzo(a)anthracene
2,4-dinitrotoluene	**	benzo(a)pyrene
2,6-dinitrotoluene	ND	benzo(b)fluoranthene[1]
1,2-diphenylhydrazine	ND	benzo(k)fluoranthene[1]
fluoranthene	ND	chrysene
4-chlorophenyl phenyl ether	ND	acenaphthylene
4-bromophenyl phenyl ether	ND	anthracene
bis(2-chloroisopropyl)ether	ND	benzo (g.h.i.) perylene
bis(2-chloroethoxy)methane	ND	fluorene
hexachlorobutadiene	ND	phenanthrene
hexachlorocyclopentadiene	*	dibenzo (a,h)anthracene
isophorone	ND	indeno(1,2,3-c,d)pyrene
naphthalene'	ND	pyrene
bis(chloromethyl)ether	**	2,3,7,8-tetrachlorodibenzo-p-dioxin

ND - Less than 1 µg/l
* - Less than 10 µg/l
** - Less than 25 µg/l

[1] Benzo(b)fluoranthene and benzo(k)fluoranthene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-2 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #570 DATE ANALYSIS COMPLETED 24 July 1981

PESTICIDES

	µg/l		µg/l
aldrin	*	a-BHC	*
dieldrin	ND	b-BHC	ND
chlordane	ND	d-BHC	*
4,4'-DDT	ND	g-BHC	ND
4,4'-DDE	ND	PCB - 1242	ND
4,4'-DDD	ND	PCB - 1254	ND
endosulfan I	*	PCB - 1221	ND
endosulfan II	*	PCB - 1232	ND
endosulfan sulfate	*	PCB - 1248	ND
endrin	*	PCB - 1260	ND
endrin aldehyde	*	PCB - 1016	ND
heptachlor	ND	toxaphene	ND
heptachlor epoxide	*		

ND - Less than 1 µg/l
* - Less than 10 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-2 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #570 DATE ANALYSIS COMPLETED 5 August 1981

VOLATILES

	µg/l		µg/l
acrolein	**	1,2-dichloropropane	ND
acrylonitrile	**	1,3-dichloropropylene[1]	*
benzene	1.4	ethylbenzene	1.2
carbon tetrachloride	*	methylene chloride	21.4
chlorobenzene	1.9	methyl chloride	*
1,2-dichloroethane	7.1	methyl bromide	13.1
1,1,1-trichloroethane	ND	bromoform	ND
1,1-dichloroethane	ND	dichlorobromomethane	ND
1,1,2-trichloroethane	ND	trichlorofluoromethane	2.4
1,1,2,2-tetrachloroethane	ND	dichlorodifluoromethane	*
chloroethane	*	chlorodibromomethane	ND
2-chloroethylvinyl ether	ND	tetrachloroethylene	1.7
chloroform	6.2	toluene	7.3
1,1-dichloroethylene	ND	trichloroethylene	1.7
1,2-trans-dichloroethylene	3.4	vinyl chloride	*

ND - Less than 1 µg/kg
* - Less than 10 µg/kg
** - Less than 100 µg/kg

[1] 1,3-cis-dichloropropylene and 1,3-trans-dichloropropylene could not be resolved, Values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-13 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #571 DATE ANALYSIS COMPLETED 16 July 1981

ACID COMPOUNDS

	µg/l
2,4,6-trichlorophenol	ND
o-chloro-m-cresol	ND
2-chlorophenol	ND
2,4-dichlorophenol	ND
2,4-dimethylphenol	ND
2-nitrophenol	ND
4-nitrophenol	*
2,4-dinitrophenol	ND
4,6-dinitro-o-cresol	ND
pentachlorophenol	ND
phenol	2.6

ND - Less than 1 µg/l
* - Less than 25 µg/l
** - Less than 250 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-13 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #571 DATA ANALYSIS COMPLETED 22 July 1981

BASE/NEUTRAL COMPOUNDS

	µg/l		µg/l
acenaphthene	ND	nitrobenzene	ND
benzidine	**	N-nitrosodimethylamine	**
1,2,4-trichlorobenzene	ND	N-nitrosodiphenylamine	**
hexachlorobenzene	ND	N-nitrosodi-n-propylamine	**
hexachloroethane	*	bis(2-ethylhexyl)phthalate	10.1
bis(2-chloroethyl)ether	*	butyl benzyl phthalate	*
2-chloronaphthalene	ND	di-n-butyl phthalate	ND
1,2-dichlorobenzene	ND	di-n-octyl phthalate	ND
1,3-dichlorobenzene	ND	diethyl phthalate	ND
1,4-dichlorobenzene	ND	dimethyl phthalate	ND
3,3'-dichlorobenzidine	*	benzo(a)anthracene	ND
2,4-dinitrotoluene	**	benzo(a)pyrene	*
2,6-dinitrotoluene	*	benzo(b)fluoranthene[1]	*
1,2-diphenylhydrazine	*	benzo(k)fluoranthene[1]	*
fluoranthene	ND	chrysene	*
4-chlorophenyl phenyl ether	*	acenaphthylene	ND
4-bromophenyl phenyl ether	*	anthracene	ND
bis(2-chloroisopropyl)ether	*	benzo (g.h.i.) perylene	**
bis(2-chloroethoxy)methane	*	fluorene	ND
hexachlorobutadiene	*	phenanthrene	ND
hexachlorocyclopentadiene	*	dibenzo (a,h)anthracene	**
isophorone	*	indeno(1,2,3-c,d)pyrene	*
naphthalene	ND	pyrene	ND
bis(chloromethyl)ether	**	2,3,7,8-tetrachlorodibenzo-p-dioxin	**

ND - Less than 1 µg/l
* - Less than 10 µg/l
** - Less than 25 µg/l

[1] Benzo(b)fluoranthene and benzo(k)fluoranthene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-13 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #571 DATE ANALYSIS COMPLETED 24 July 1981

PESTICIDES

	µg/l		µg/l
aldrin	*	a-BHC	*
dieldrin	*	b-BHC	*
chlordane	ND	d-BHC	*
4,4'-DDT	*	g-BHC	*
4,4'-DDE	*	PCB - 1242	ND
4,4'-DDD	*	PCB - 1254	ND
endosulfan I	*	PCB - 1221	ND
endosulfan II	*	PCB - 1232	ND
endosulfan sulfate	*	PCB - 1248	ND
endrin	*	PCB - 1260	ND
endrin aldehyde	*	PCB - 1016	ND
heptachlor	*	toxaphene	ND
heptachlor epoxide	*		

ND - Less than 1 µg/l
* - Less than 10 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-13 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #571 DATE ANALYSIS COMPLETED 5 August 1981

VOLATILES

	µg/l		µg/l
acrolein	**	1,2-dichloropropane	ND
acrylonitrile	**	1,3-dichloropropylene[1]	*
benzene	ND	ethylbenzene	4.4
carbon tetrachloride	*	methylene chloride	ND
chlorobenzene	ND	methyl chloride	*
1,2-dichloroethane	ND	methyl bromide	*
1,1,1-trichloroethane	ND	bromoform	ND
1,1-dichloroethane	ND	dichlorobromomethane	ND
1,1,2-trichloroethane	ND	trichlorofluoromethane	33.8
1,1,2,2-tetrachloroethane	ND	dichlorodifluoromethane	*
chloroethane	*	chlorodibromomethane	ND
2-chloroethylvinyl ether	ND	tetrachloroethylene	4.6
chloroform	7.8	toluene	ND
1,1-dichloroethylene	ND	trichloroethylene	1.8
1,2-trans-dichloroethylene	ND	vinyl chloride	*

ND - Less than 1 µg/kg
 * - Less than 10 µg/kg
 ** - Less than 100 µg/kg

[1] 1,3-cis-dichloropropylene and 1,3-trans-dichloropropylene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-25 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #572 DATE ANALYSIS COMPLETED 16 July 1981

ACID COMPOUNDS

	µg/l
2,4,6-trichlorophenol	ND
o-chloro-m-cresol	ND
2-chlorophenol	ND
2,4-dichlorophenol	ND
2,4-dimethylphenol	ND
2-nitrophenol	ND
4-nitrophenol	*
2,4-dinitrophenol	**
4,6-dinitro-o-cresol	*
pentachlorophenol	ND
phenol	52.8

ND - Less than 1 µg/l
* - Less than 25 µg/l
** - Less than 250 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-25 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #572 DATA ANALYSIS COMPLETED [illegible] July 1981

BASE/NEUTRAL COMPOUNDS

	µg/l		µg/l
acenaphthene	ND	nitrobenzene	*
benzidine	**	N-nitrosodimethylamine	**
1,2,4-trichlorobenzene	ND	N-nitrosodiphenylamine	**
hexachlorobenzene	ND	N-nitrosodi-n-propylamine	**
hexachloroethane	*	bis(2-ethylhexyl)phthalate	3.5
bis(2-chloroethyl)ether	*	butyl benzyl phthalate	*
2-chloronaphthalene	ND	di-n-butyl phthalate	ND
1,2-dichlorobenzene	ND	di-n-octyl phthalate	ND
1,3-dichlorobenzene	ND	diethyl phthalate	ND
1,4-dichlorobenzene	ND	dimethyl phthalate	ND
3,3'-dichlorobenzidine	*	benzo(a)anthracene	ND
2,4-dinitrotoluene	**	benzo(a)pyrene	*
2,6-dinitrotoluene	*	benzo(b)fluoranthene[1]	*
1,2-diphenylhydrazine	ND	benzo(k)fluoranthene[1]	*
fluoranthene	ND	chrysene	ND
4-chlorophenyl phenyl ether	*	acenaphthylene	ND
4-bromophenyl phenyl ether	*	anthracene	ND
bis(2-chloroisopropyl)ether	*	benzo (g.h.i.) perylene	*
bis(2-chloroethoxy)methane	*	fluorene	ND
hexachlorobutadiene	*	phenanthrene	ND
hexachlorocyclopentadiene	*	dibenzo (a,h)anthracene	**
isophorone	*	indeno(1,2,3-c,d)pyrene	*
naphthalene	ND	pyrene	ND
bis(chloromethyl)ether	**	2,3,7,8-tetrachlorodibenzo-p-dioxin	**

ND - Less than 1 µg/l
 * - Less than 10 µg/l
** - Less than 25 µg/l

[1] Benzo(b)fluoranthene and benzo(k)fluoranthene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-25 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #572 DATE ANALYSIS COMPLETED 24 July 1981

PESTICIDES

	µg/l		µg/l
aldrin	*	a-BHC	*
dieldrin	ND	b-BHC	ND
chlordane	ND	d-BHC	*
4,4'-DDT	ND	g-BHC	ND
4,4'-DDE	ND	PCB - 1242	ND
4,4'-DDD	ND	PCB - 1254	ND
endosulfan I	*	PCB - 1221	ND
endosulfan II	*	PCB - 1232	ND
endosulfan sulfate	*	PCB - 1248	ND
endrin	*	PCB - 1260	ND
endrin aldehyde	*	PCB - 1016	ND
heptachlor	ND	toxaphene	ND
heptachlor epoxide	*		

ND - Less than 1 µg/l
* - Less than 10 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-25 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #572 DATE ANALYSIS COMPLETED 5 August 1981

VOLATILES

	µg/l		µg/l
acrolein	**	1,2-dichloropropane	ND
acrylonitrile	**	1,3-dichloropropylene[1]	*
benzene	1.1	ethylbenzene	21.3
carbon tetrachloride	*	methylene chloride	11.4
chlorobenzene	ND	methyl chloride	*
1,2-dichloroethane	5.4	methyl bromide	*
1,1,1-trichloroethane	ND	bromoform	ND
1,1-dichloroethane	ND	dichlorobromomethane	ND
1,1,2-trichloroethane	ND	trichlorofluoromethane	*
1,1,2,2-tetrachloroethane	ND	dichlorodifluoromethane	*
chloroethane	*	chlorodibromomethane	ND
2-chloroethylvinyl ether	ND	tetrachloroethylene	48.4
chloroform	ND	toluene	45.3
1,1-dichloroethylene	*	trichloroethylene	4.4
1,2-trans-dichloroethylene	23.1	vinyl chloride	*

ND - Less than 1 µg/kg
* - Less than 10 µg/kg
** - Less than 100 µg/kg

[1] 1,3-cis-dichloropropylene and 1,3-trans-dichloropropylene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-31 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #573 DATE ANALYSIS COMPLETED 16 July 1981

ACID COMPOUNDS

	µg/l
2,4,6-trichlorophenol	*
o-chloro-m-cresol	ND
2-chlorophenol	26.0
2,4-dichlorophenol	ND
2,4-dimethylphenol	ND
2-nitrophenol	ND
4-nitrophenol	*
2,4-dinitrophenol	*
4,6-dinitro-o-cresol	ND
pentachlorophenol	ND
phenol	2.6

ND - Less than 1 µg/l
* - Less than 25 µg/l
** - Less than 250 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-31 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #573 DATA ANALYSIS COMPLETED 22 July 1981

BASE/NEUTRAL COMPOUNDS

	µg/l		µg/l
acenaphthene	ND	nitrobenzene	ND
benzidine	**	N-nitrosodimethylamine	**
1,2,4-trichlorobenzene	ND	N-nitrosodiphenylamine	**
hexachlorobenzene	ND	N-nitrosodi-n-propylamine	**
hexachloroethane	ND	bis(2-ethylhexyl)phthalate	*
bis(2-chloroethyl)ether	ND	butyl benzyl phthalate	16.2
2-chloronaphthalene	ND	di-n-butyl phthalate	ND
1,2-dichlorobenzene	ND	di-n-octyl phthalate	1.4
1,3-dichlorobenzene	ND	diethyl phthalate	ND
1,4-dichlorobenzene	ND	dimethyl phthalate	ND
3,3'-dichlorobenzidine	*	benzo(a)anthracene	ND
2,4-dinitrotoluene	**	benzo(a)pyrene	ND
2,6-dinitrotoluene	ND	benzo(b)fluoranthene[1]	ND
1,2-diphenylhydrazine	ND	benzo(k)fluoranthene[1]	ND
fluoranthene	ND	chrysene	ND
4-chlorophenyl phenyl ether	ND	acenaphthylene	ND
4-bromophenyl phenyl ether	ND	anthracene	ND
bis(2-chloroisopropyl)ether	ND	benzo (g.h.i.) perylene	*
bis(2-chloroethoxy)methane	ND	fluorene	ND
hexachlorobutadiene	ND	phenanthrene	ND
hexachlorocyclopentadiene	*	dibenzo (a,h)anthracene	*
isophorone	ND	indeno(1,2,3-c,d)pyrene	ND
naphthalene'	ND	pyrene	ND
bis(chloromethyl)ether	**	2,3,7,8-tetrachlorodibenzo-p-dioxin	**

ND - Less than 1 µg/l
* - Less than 10 µg/l
** - Less than 25 µg/l

[1] Benzo(h)fluoranthene and benzo(k)fluoranthene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-31 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #573 DATE ANALYSIS COMPLETED 24 July 1981

PESTICIDES

	µg/l		µg/l
aldrin	ND	a-BHC	*
dieldrin	ND	b-BHC	ND
chlordane	ND	d-BHC	8.5
4,4'-DDT	ND	g-BHC	ND
4,4'-DDE	ND	PCB - 1242	ND
4,4'-DDD	ND	PCB - 1254	ND
endosulfan I	*	PCB - 1221	ND
endosulfan II	*	PCB - 1232	ND
endosulfan sulfate	*	PCB - 1248	ND
endrin	*	PCB - 1260	ND
endrin aldehyde	*	PCB - 1016	ND
heptachlor	ND	toxaphene	ND
heptachlor epoxide	*		

ND - Less than 1 µg/l
* - Less than 10 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-31 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #573 DATE ANALYSIS COMPLETED 5 August 1981

VOLATILES

	µg/l		µg/l
acrolein	**	1,2-dichloropropane	ND
acrylonitrile	**	1,3-dichloropropylene[1]	*
benzene	ND	ethylbenzene	30.4
carbon tetrachloride	*	methylene chloride	1.4
chlorobenzene	9.6	methyl chloride	*
1,2-dichloroethane	4.2	methyl bromide	*
1,1,1-trichloroethane	1.4	bromoform	ND
1,1-dichloroethane	ND	dichlorobromomethane	ND
1,1,2-trichloroethane	ND	trichlorofluoromethane	2.6
1,1,2,2-tetrachloroethane	ND	dichlorodifluoromethane	*
chloroethane	*	chlorodibromomethane	ND
2-chloroethylvinyl ether	ND	tetrachloroethylene	19.3
chloroform	3.1	toluene	30.9
1,1-dichloroethylene	ND	trichloroethylene	13.1
1,2-trans-dichloroethylene	40.2	vinyl chloride	*

ND - Less than 1 µg/kg
* - Less than 10 µg/kg
** - Less than 100 µg/kg

[1] 1,3-cis-dichloropropylene and 1,3-trans-dichloropropylene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-35 DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #574 DATE ANALYSIS COMPLETED 16 July 1981

ACID COMPOUNDS

	µg/l
2,4,6-trichlorophenol	*
o-chloro-m-cresol	ND
2-chlorophenol	1414.7
2,4-dichlorophenol	ND
2,4-dimethylphenol	ND
2-nitrophenol	ND
4-nitrophenol	*
2,4-dinitrophenol	**
4,6-dinitro-o-cresol	*
pentachlorophenol	*
phenol	159.0

ND - Less than 1 µg/l
* - Less than 25 µg/l
** - Less than 250 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-35 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #574 DATA ANALYSIS COMPLETED 22 July 1981

BASE/NEUTRAL COMPOUNDS

	µg/l		µg/l
acenaphthene	ND	nitrobenzene	*
benzidine	**	N-nitrosodimethylamine	**
1,2,4-trichlorobenzene	ND	N-nitrosodiphenylamine	**
hexachlorobenzene	ND	N-nitrosodi-n-propylamine	**
hexachloroethane	ND	bis(2-ethylhexyl)phthalate	**
bis(2-chloroethyl)ether	ND	butyl benzyl phthalate	18.4
2-chloronaphthalene	ND	di-n-butyl phthalate	*
1,2-dichlorobenzene	ND	di-n-octyl phthalate	ND
1,3-dichlorobenzene	ND	diethyl phthalate	ND
1,4-dichlorobenzene	ND	dimethyl phthalate	ND
3,3'-dichlorobenzidine	*	benzo(a)anthracene	ND
2,4-dinitrotoluene	**	benzo(a)pyrene	ND
2,6-dinitrotoluene	*	benzo(b)fluoranthene[1]	ND
1,2-diphenylhydrazine	ND	benzo(k)fluoranthene[1]	ND
fluoranthene	ND	chrysene	ND
4-chlorophenyl phenyl ether	ND	acenaphthylene	ND
4-bromophenyl phenyl ether	ND	anthracene	ND
bis(2-chloroisopropyl)ether	ND	benzo (g.h.i.) perylene	*
bis(2-chloroethoxy)methane	ND	fluorene	ND
hexachlorobutadiene	ND	phenanthrene	ND
hexachlorocyclopentadiene	*	dibenzo (a,h)anthracene	*
isophorone	ND	indeno(1,2,3-c,d)pyrene	ND
naphthalene'	3.8	pyrene	ND
bis(chloromethyl)ether	**	2,3,7,8-tetrachlorodibenzo-p-dioxin	**

ND - Less than 1 µg/l
* - Less than 10 µg/l
** - Less than 25 µg/l

[1] Benzo(b)fluoranthene and benzo(k)fluoranthene could not be resolved, values reported indicate the sum of both compounds.

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-35 (NPDES) DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #574 DATE ANALYSIS COMPLETED 24 July 1981

PESTICIDES

	µg/l		µg/l
aldrin	*	a-BHC	ND
dieldrin	ND	b-BHC	ND
chlordane	940	d-BHC	*
4,4'-DDT	ND	g-BHC	ND
4,4'-DDE	ND	PCB - 1242	ND
4,4'-DDD	ND	PCB - 1254	ND
endosulfan I	*	PCB - 1221	ND
endosulfan II	*	PCB - 1232	ND
endosulfan sulfate	*	PCB - 1248	ND
endrin	*	PCB - 1260	ND
endrin aldehyde	*	PCB - 1016	ND
heptachlor	ND	toxaphene	ND
heptachlor epoxide	*		

ND - Less than 1 µg/l
 * - Less than 10 µg/l

SUMMARY OF ORGANIC PRIORITY POLLUTANT ANALYSIS

CLIENT West Lake

CLIENT I.D. BH-35 DATE SAMPLE RECEIVED 6 July 1981

RMC I.D. #574 DATE ANALYSIS COMPLETED 5 August 1981

VOLATILES

	µg/l		µg/l
acrolein	**	1,2-dichloropropane	ND
acrylonitrile	**	1,3-dichloropropylene[1]	*
benzene	15.7	ethylbenzene	487.9
carbon tetrachloride	22.4	methylene chloride	26.4
chlorobenzene	ND	methyl chloride	*
1,2-dichloroethane	81.6	methyl bromide	57.6
1,1,1-trichloroethane	ND	bromoform	ND
1,1-dichloroethane	18.4	dichlorobromomethane	ND
1,1,2-trichloroethane	ND	trichlorofluoromethane	147.9
1,1,2,2-tetrachloroethane	ND	dichlorodifluoromethane	*
chloroethane	*	chlorodibromomethane	ND
2-chloroethylvinyl ether	*	tetrachloroethylene	45.3
chloroform	25.1	toluene	277.1
1,1-dichloroethylene	5.2	trichloroethylene	724.9
1,2-trans-dichloroethylene	7.7	vinyl chloride	**

ND - Less than 1 µg/kg
* - Less than 10 µg/kg
** - Less than 100 µg/kg

[1] 1,3-cis-dichloropropylene and 1,3-trans-dichloropropylene could not be resolved, values reported indicate the sum of both compounds.

Chemical Analysis of Radioactive Material From Areas 1 and 2

Table 13

Concentration in ppm

	Offsite Bkg Sample	Area 1 Surface (#101)	Area 1 Surface (#102)	Area 1 Borehole (#103)	Area 2 Surface (#104)	Area 2 Surface (#105)
Barium	250	300	1811	2386	1158	1197
Lead	16	15	108	121	11	50
Zinc	132	146	94	76	28	167
Sulfate	20	15	108	121	11	50

Summary of Background Measurements in the Vicinity of West Lake Landfill,
St. Louis County Missouri

Table 14

Sample Type	Background Location: Earth City	Taussig Road	Old St. Charles Rock Road
Flux (Av)(pCi/m2.s)	0.50 +/- 54%	0.58 +/- 27%	0.50 +/- 30%
Exposure Rate (uR/hr)	10.6	8.0	--------------
Soil Conc. (Ra-226 pCi/gm)	2.6 +/- 23%	2.5 +/- 19%	--------------
HVAS (W.L.)	1.1E-3	5E-3	1.7E-3

Target Criteria and Measurements LLDs for West Lake Landfill

Table 15

Soil Contaminants

Nuclide	Target Criteria	LLD
Ra-226	5pCi/g	1pCi/g
Total U	15pCi/g	3pCi/g
U-238	30pCi/g	6pCi/g
U-235	30pCi/g	6pCi/g
Th-232	5pCi/g	1pCi/g
Th-230	15pCi/g	3pCi/g

Water and Airborne Contaminants

Nuclide	Target Criteria	LLD
All	MPC Unrestricted	20% MPC
Radon Daughters	0.03 W.L.	0.006 W.L.
Ra-226 (water)	3E-8 uCi/ml	6E-9 uCi/ml

External Radiation

Nuclide	Target Criteria	LLD
All	20 uR/hr	4 uR/hr

APPENDIX I

Radiological Survey Instruments and Methods

A. Portable Survey Instrument

The portable survey instruments used at West Lake included two complete sets of Johnson equipment, which consist of battery operated rate meters, scalers and alpha, beta and gamma probes. These systems (see Figure I-1) are totally portable and can be used in the field for both measurements and sample counting.

The alpha probes use a ZnS (Ag) scintillation detector; the beta detector is a thin window (1.4mg/cm2 mica) GM tube, and the gamma detector is a 2" by 2" NaI(Tl) crystal. The alpha and beta probes were calibrated with "NBS traceable" sources at the RMC calibration facility in Philadelphia and the gamma scintillator was cross-calibrated with a primary ionization chamber system, described below.

B. Ionization Chamber System

External gamma dose rates were accurately measured with the RMC constructed Tissue Equivalent Ionization Chamber System (Figure I-2). This system consisted of a 16 liter tissue equivalent, gas filled ionization chamber (Shonka chamber), a Keithley vibrating capacitor electrometer, a printer and battery pack. It is capable of measuring dose rates at background levels to a precision of a few percent.

Since this system is bulky and somewhat fragile, it is not as suited for extensive field measurements as a smaller, lightweight NaI(Tl) portable survey instrument. Therefore, the NaI(Tl) detector was used for the majority of the field gamma measurements. Since this detector's response is energy dependent, it cannot be used as a "micro R meter" unless it is initially calibrated for such use.

The calibration performed by RMC consisted of accurately measuring the exposure rate at several locations at West Lake Landfill, using the Tissue Equivalent Ionization Chamber, then recording NaI(Tl) measurements at the same location. In this manner a set of NaI(Tl) count-rate versus exposure rates were obtained and a uR/hr calibration factor established, as shown in Figure I-3.

Due to the energy dependence of the NaI detector, this conversion factor will apply only to the radionuclides and geometries for which the calibrations were made. In the case of West Lake, analyses have verified the presence only of naturally occurring nuclides of the uranium series (Ra-226 and daughters), thorium series and potassium. Therefore, the conversion factor established at West Lake will apply only to naturally occurring radionuclides distributed in soil.

C. Mobile Lab Gamma Analysis System

The mobile lab gamma analysis system (Figure I-4) consists of a PGT 15% efficient (relative to a 3" x 3" NaI(Tl) crystal) intrinsic germanium (IG) detector, shield and Tennecomp TP-50 laboratory computer data acquisition module. The analysis system was calibrated for all counting geometries with an NBS supplied Eu-152 source.

Each count was analyzed by a computer program for determination of gamma energies and peak areas. All results were printed out immediately following analysis on-site, and data was stored on floppy discs for future analysis, as needed.

Samples were sealed in counting containers and stored to allow for complete ingrowth of radon and daughters, whenever possible. In these cases, Ra-226 was determined by counting the daughter Bi-214 gamma-ray lines at 609 and 1764 KeV. Pb-214 was determined by the 295 and 352 KeV lines, U-238 from its 93 KeV line, Ra-223 from its 270 KeV line, Rn-219 from its 401 KeV line, Pb-211 from its 405 and 832 KeV lines, Th-227 from its 237 KeV line and K-40 from its 1462 KeV line.

Typical LLDs for Ra-226 were 0.1 pCi/g in soil and vegetation, and 0.4 pCi/l in water. For Rn-219 daughters on air filters, LLDs were 0.4 pCi/l. The LLD for U-238 in soil was on the order of 1 pCi/g.

D. Auger Hole Logging System

Detailed logging of selected auger holes was performed with the system shown in Figure I-5. This system consists of a custom designed EG&G Ortec intrinsic germanium detector (10% eff) with a narrow dewar, coupled to a Tracor-Northern

1750 MCA used for data acquisition and initial field evaluations. Data was stored on a tape cassette recorder, then transferred to the lab computer system for final analysis. The entire system, including an NIM module power supply with a bias power supply and amplifier, was powered in the field by a portable 5000 watt gasoline-driven generator.

The logging system was calibrated as described in Attachment 1. Field counting times varied from 2 minutes to 10 minutes at each location, depending upon the level of activity present. Typical LLDs for this system and relatively short count times are 0.3 pCi/g for Bi-214, 1 pCi/g for U-238, 0.2 pCi/g for Pb-212 and 0.1 pCi/g for K-40.

The field use of this system was somewhat limited by initial failure due to high humidity effects on the pre-amp components and thermal insulation of the detector housing. These problems were partially corrected by sealing the detector in an outer container and allowing dry air to flow through the container.

E. Radon Analysis Systems

Radon flux was determined using the accumulator system shown in Figure I-6, which is similar to those used by Wilkening [1] and others. Accumulation times varied from 15 minutes to 2 hours. Gas samples were drawn and counted in the EDA Radon Detector, usually 2 hours after sampling, to allow for daughter ingrowth. Standard MSA charcoal canisters were used for the canister method, as described by Countess [2].

F. Alpha-Beta Counting System.

All samples were counted for gross alpha or beta activity on the Gamma Products low background gas flow proportional counter, shown in Figure I-7. The system is automatic and can be programmed for a variety of counting parameters.

REFERENCES

[1] M. Wilkening, "Measurement of Radon Flux by the Accumulation Method", Workshops on Methods for Measuring Radiation in and Around Uranium Mills, 3, 9, 1977, pp. 131-137.

[2] R. J. Countess, "Measurements of Rn-222 Flux with Charcoal Canisters" ibid. pp. 139-147.

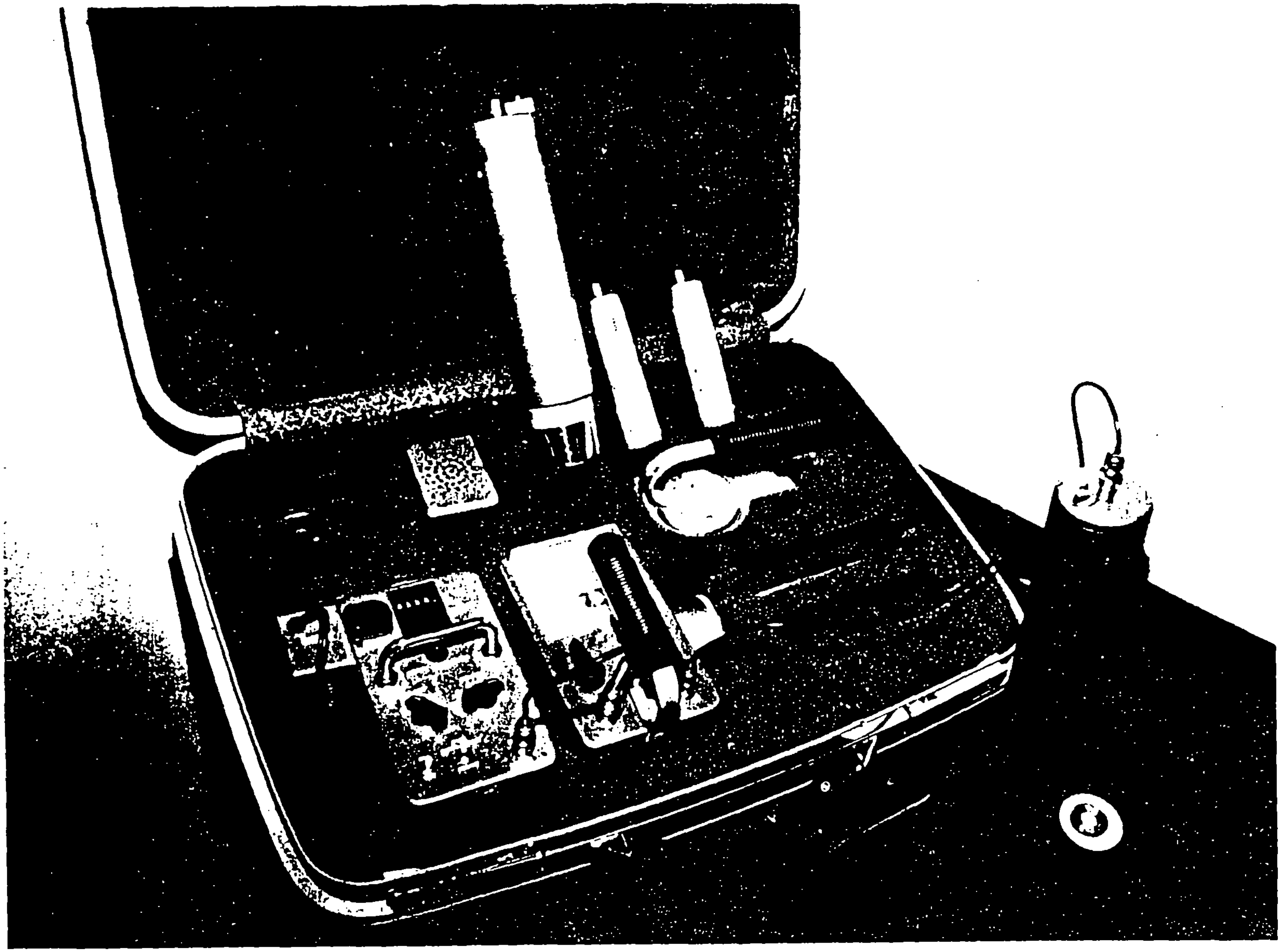


Figure I-1. Portable Survey Instrument Kit.

Landfill site.

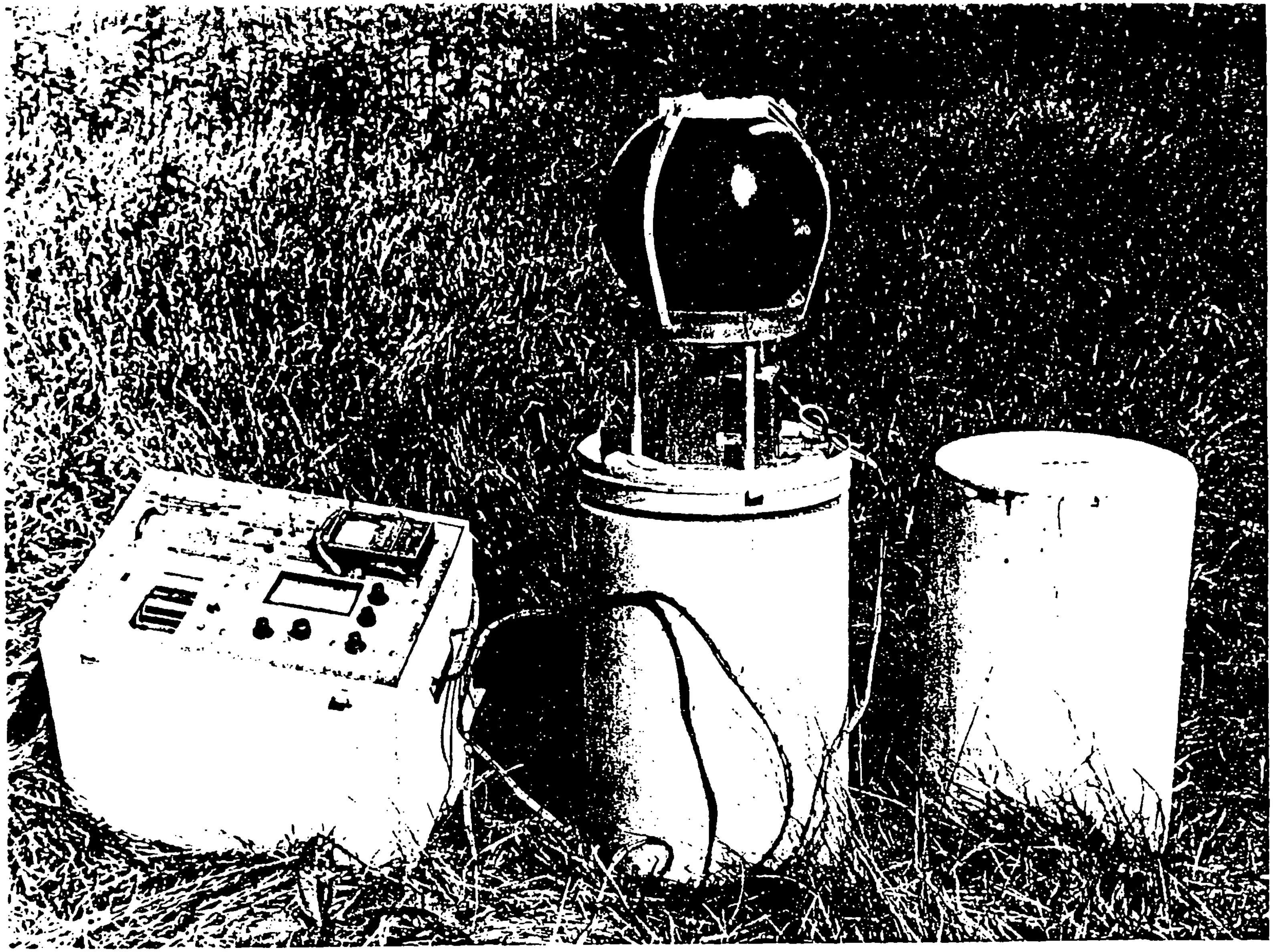


Figure I-2. High sensitivity tissue equivalent ionization chamber system.

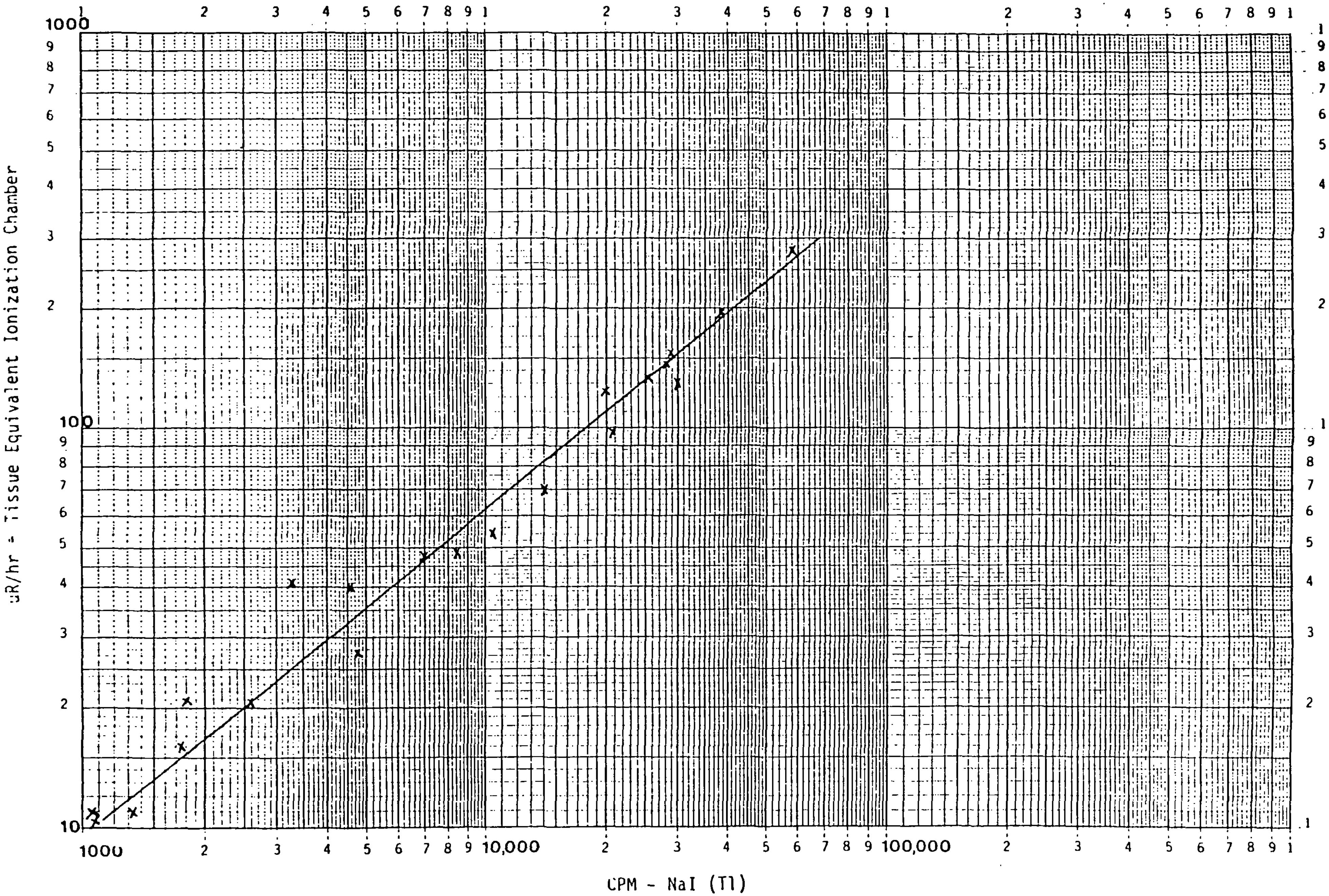


Figure I-3. Ion chamber exposure rates versus NaI (Tl) count rates, West Lake Landfill site.

Figure I-4. Interior of mobile lab showing gamma counting system and other equipment.

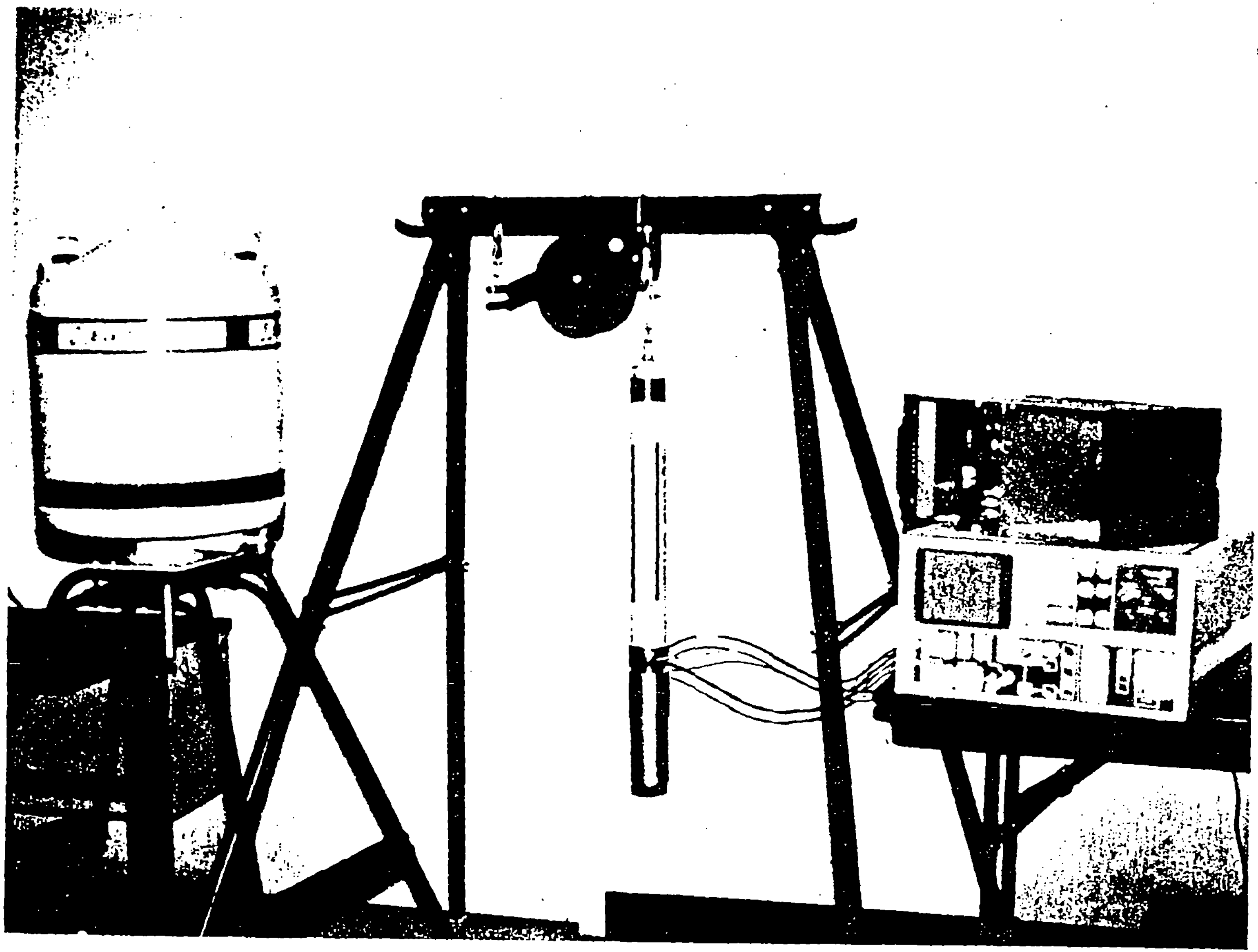


Figure I-5. In-situ auger hole logging system with intrinsic germanium detector and narrow dewar assembly, data acquisition equipment and storage/fill dewar.

Figure I-6. Radon sampling cells, pump, and gas analyzer, sitting atop a radon accumulator tub.

Figure I-7. Automatic beta-gamma gas flow proportional counter.

ATTACHMENT 1 TO APPENDIX I

INTRINSIC GERMANIUM WELL LOG DETECTOR CALIBRATION

The intrinsic germanium detector was connected to the pulse height analysis system consisting of the following components:

Ortec Model 459 High Voltage Power Supply
Canberra 2011 Spectroscopy Amplifier
Tracor Northern 1750 MCA
Teletype Model 43 Printer

Gain and voltage supply settings were adjusted to obtain an energy spectrum of 0 to 2000 kev, which corresponds to approximately 1 kev per channel.

Calibration of the well logging system was performed using the calibration rig shown in Figure 1. This rig is constructed as a series of four concentric rings surrounding a 6 inch PVC casing. Each ring contains thin plastic tubes 1-1/4" diameter by 36" long. A set of "source rods" and "background rods" were prepared and loaded into these tubes in a variety of configurations for the various calibration and test counts.

The geometry of the rig is such that the distance from the center of the casing (or detector) to the center of the innermost ring is 3.75 inches, to the center of the second ring is 5.0 inches, to the center of the third ring is 6.25

inches, and to the center of the fourth ring is 7.50 inches. All voids between tubes were filled with low background sand. It was determined that the ratio of source volume in each ring to the total ring area was about 0.6. Hence, when source rods were fully loaded into a given ring, the activity counted represented approximately 60% of the total area (volume) the detector viewed, and counts were adjusted accordingly.

Each source tube is a 12 inch high by 1 inch diameter tube filled with a material containing Eu-152. The source material was prepared by mixing the standard Eu-152 source solution with plaster of paris, at a constant ratio designed to give a uniform specific activity of 440 pCi/gram. Background rods were filled with "clean" plaster of paris. Plaster of paris was chosen because of its ease of handling, ability to uniformly distribute the source throughout the material, and its density, which approximates that of common soil. (Density of soil, 1.7-2.3 g/cubic cm; density of plaster, 1.5 g/cubic cm; density of sand, 1.4 g/cubic cm)

Four different configurations of source and blank tubes were used for the calibration. Source tubes were placed three high in one of the four concentric rings of the rig for each count while the balance of the rig was filled with blanks. These configurations correspond to the source material being a radial distance of 3.75, 5.00, 6.25 and 7.50 inches from the detector.

Each configuration was counted for 900 seconds, and the area under each of the eight major Eu-152 photopeaks determined for each count.

Calculation of counts per gamma per gram was determined by the following method:

NCNTS/GAMMA/GRAM =

[NCNTS]/[(440pCi/g)(3.7E-2d/s/pCi)(900s)(ABUNDANCEgamma/d)]

For each gamma energy, the net counts/gamma/gram vs distance from the center of the detector was listed. These response curves were then plotted for each energy, for distances and activities which extend to zero net counts. This represents an "infinite" distance from the detector. Using these curves, the total counts from the detector to an infinite distance was calculated by integrating the area under the curve using Simpson's rule for approximating integrals. Of prime importance is the integral from 2 inches to infinity, since this is the area the detector will view when placed inside a 4 inch PVC casing.

Finally, the integrated net count/gamma/gram, from 2 inches to infinity, was plotted vs energy, for each of the Eu-152 photons. With this efficiency curve, a specific activity in soil (pCi/gram) can be determined from a bore hole count, assuming the radionuclide can be identified and its gamma abundance determined. The calculation is:

count, with a 95% confidence level and precision of 0.4 pCi/g.

Figure 1

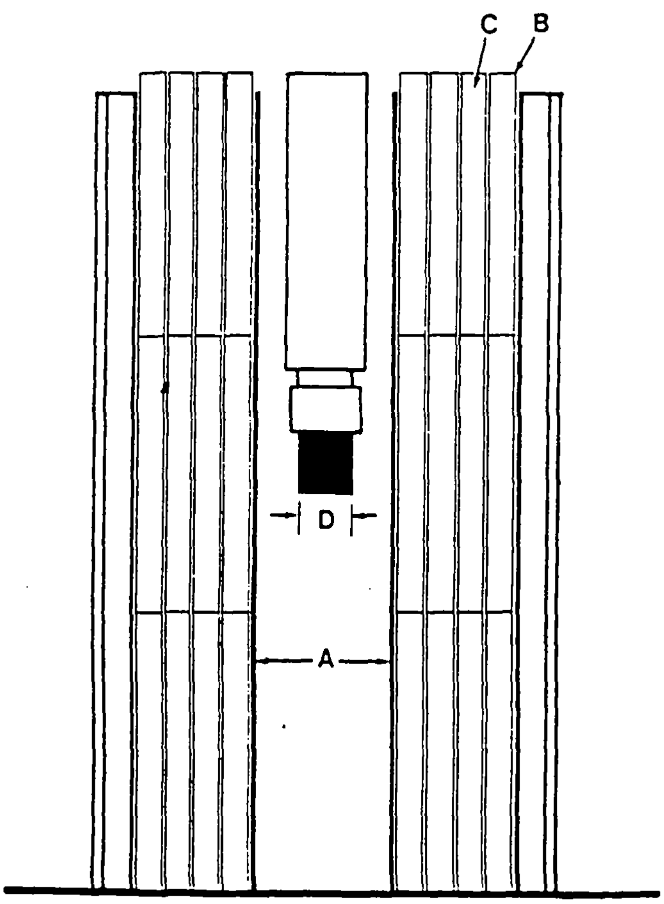
CALIBRATION RIG ASSEMBLY

"A" - 6" I.D. PVC Pipe

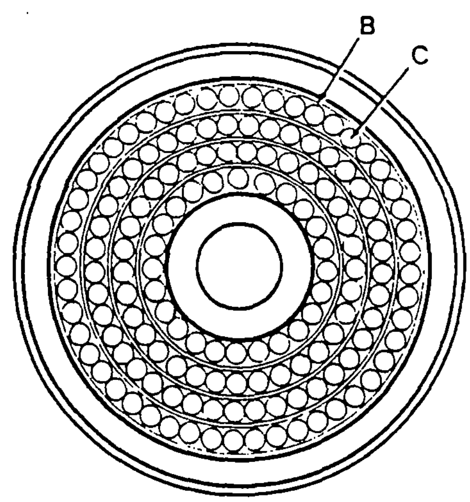
"B" - 1.25" diameter x 36" long butyrate source holder tubes

"C" - 1" diameter x 12" long source tubes. 3 per holder tube

"D" - IG Detector



Cross Section



Top View

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This report presents the results of a radiological survey of the West Lake Landfill, St. Louis County, Missouri, performed by Radiation Management Corporation during the spring and summer of 1981. Measurements were made to determine external radiation levels, concentrations of airborne contaminants and the identity and concentrations of subsurface deposits. Results indicate that large volumes of uranium ore residues, probably originating from the Hazelwood, Missouri, Latty Avenue site, have been buried at the West Lake Landfill. Two areas of contamination, covering more than 15 acres and located at depths of up to 20 feet below the present surface, have been identified. There is no indication that significant quantities of contaminants are moving off-site at this time.

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Summary Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

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Radioactive Material in the West Lake Landfill

Summary Report

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Office of Nuclear Material Safety and Safeguards
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Washington, DC 20555

ABSTRACT

The West Lake Landfill is located near the city of St. Louis in Bridgeton, St. Louis County, Missouri. The site has been used since 1962 for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris.

This report summarizes the circumstances of the radioactive material in the West Lake Landfill. The radioactive material resulted from the processing of uranium ores and the subsequent sale by the AEC of processing residues. Primary emphasis is on the radiological environmental aspects as they relate to potential disposition of the material. It is concluded that remedial action is called for.

CONTENTS

1 INTRODUCTION AND BACKGROUND

This report summarizes the circumstances of the radioactive material in the West Lake Landfill (Figure 1), in particular, the radiological environmental aspects as they relate to potential disposition of the material.

The West Lake Landfill, Inc. property is a 200 acre tract in Bridgeton, St. Louis County, Missouri, on the outskirts of the city of St. Louis. It is about 4 miles west of St. Louis' Lambert Field International Airport, near the intersection of interstate highways I-70 and I-270. Limestone was quarried there from 1939 to 1987. Also on the property is an industrial complex where concrete ingredients are measured and combined, and where asphalt aggregate is prepared. Since 1962, portions of the property have been used as landfills for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. In 1973, soil contaminated with radioactive material was placed in a landfill there.

The radioactive material originated with uranium-ore-processing residues which had been stored at Lambert Airport by the U.S. Atomic Energy Commission (AEC), and which were sold in early 1966 to the Continental Mining and Milling Company, of Chicago, Illinois. The AEC's invitation to bid listed the following residues for purchase: 74,000 tons of Belgian Congo pitchblende raffinate containing about 113 tons of uranium; 32,500 tons of Colorado raffinate containing about 48 tons of uranium; and 8700 tons of leached barium sulfate containing about 7 tons of uranium. The material was moved from the airport during 1966 to nearby 9200 Latty Avenue, Hazelwood, Missouri. In January 1967, the Commercial Discount Corporation of Chicago took possession of the residues to remove moisture and to ship the residues to the Cotter Corporation facilities in Canon City, Colorado. In December 1969, the remaining material was sold to the Cotter Corporation. In the following four years, the residues, with the principal exception of the 8700 tons of leached barium sulfate, were shipped to Canon City.[1]

In April 1974, Region III representatives of NRC's Office of Inspection and Enforcement visited the Cotter Corporation's Latty Avenue site to check on the progress of the decommissioning activities being performed there. This inspection disclosed that in 1973 Cotter Corporation had disposed of approximately 8700 tons of leached barium sulfate residues mixed with 39,000 tons of top soil at a local landfill.[1]

By letter dated June 2, 1976, the Missouri Department of Natural Resources (MDNR) forwarded to the NRC's Region III office newspaper articles which alleged that only 9000 tons of waste had been moved from the Latty Avenue site rather than 40,000 tons and that it was moved to the West Lake Landfill rather than to the St. Louis Landfill No. 1. Region III personnel investigated the allegations and found that 43,000 tons of waste and soil had been removed from the Latty Avenue site and had been dumped at the West Lake Landfill in Bridgeton, and that the waste was covered with only about 3 feet of soil.[1]

Discussion with the West Lake Landfill operators indicated that all of the material from Latty Avenue had been disposed of in one area; however, an aerial

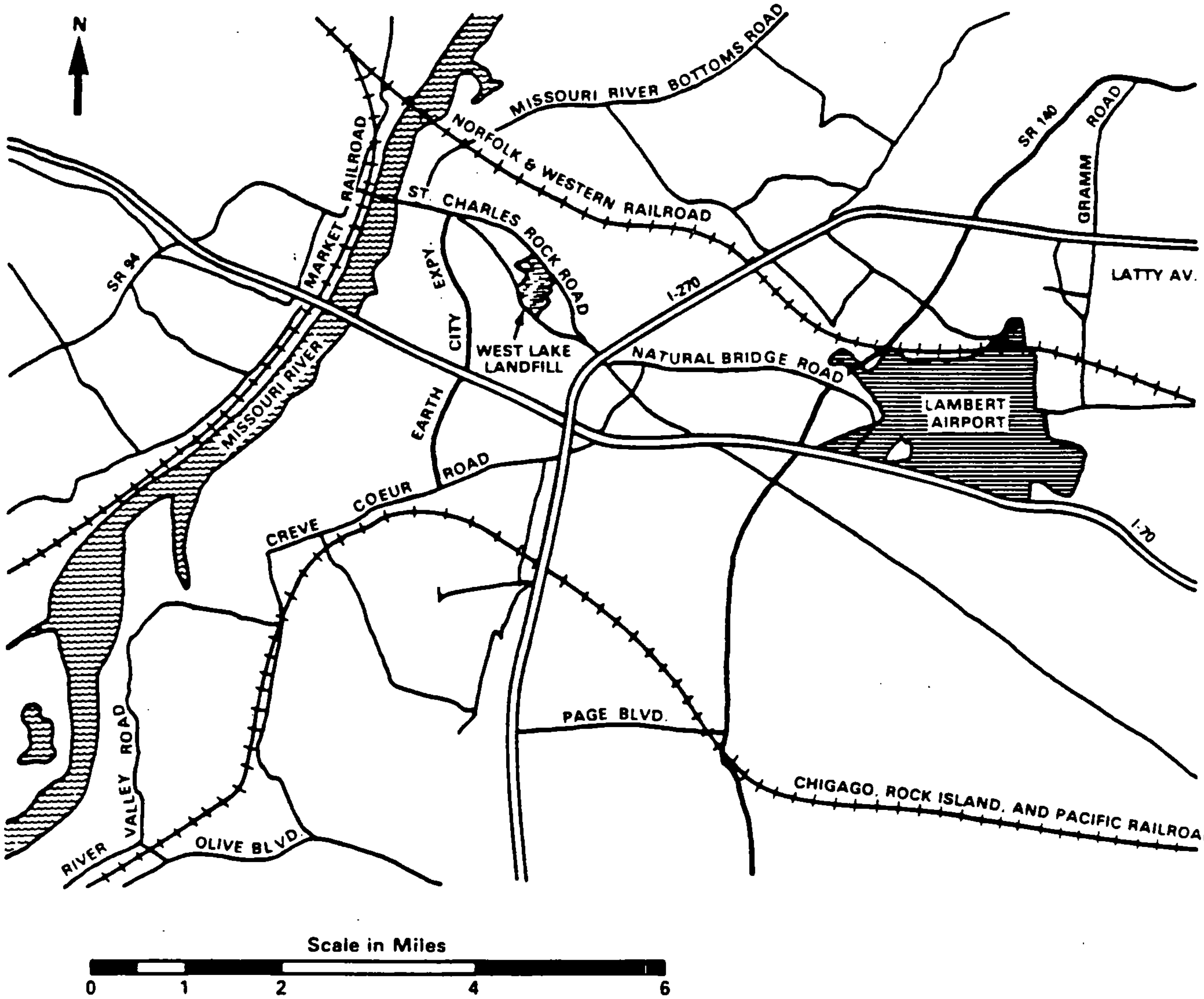

Figure 1 Location of West Lake Landfill

survey of the site identified two areas of contamination. The second contaminated area is identified as Area 1 in Figure 2.[2] Subsequently, the NRC sponsored other studies that were directed at determining the radiological status of the landfill. An extensive survey was initiated in November 1980 by the Radiation Management Corporation (RMC) under contract to the NRC. The findings were published in May 1982 in NUREG/CR-2722, "Radiological Survey of the West Lake Landfill, St. Louis County, Missouri."[3] In March 1983, the NRC through Oak Ridge Associated Universities (ORAU) contracted with the University of Missouri-Columbia (UMC), Department of Civil Engineering, to describe the environmental characteristics of the site, conduct an engineering evaluation, and propose possible remedial measures for dealing with the radioactive waste at the West Lake Landfill. In May 1986, ORAU sampled water from wells on and close to the landfill to determine if the radioactive material had migrated into the groundwater. A report is being prepared detailing the results of the investigations conducted by UMC and ORAU.[2]

Information from all these sources and from NRC site visits forms the basis for this report.

2 DESCRIPTION OF THE SITE

Location

The 200-acre West Lake Landfill site is situated on the southwest side of St. Charles Rock Road in Bridgeton, St. Louis County, Missouri (Figure 1).[2] It is about 16 miles northwest of the downtown area of the city of St. Louis, and about 4 miles west of Lambert Field International Airport (Figure 1). It is approximately 1.2 miles from the Missouri River.

History

The West Lake Landfill has been used since 1962 for the disposal of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. Between 1939 and the spring of 1987, limestone was quarried there. Landfill operations filled in some of the excavated pits from the quarry operations. Also on the property is an active industrial complex in which concrete ingredients are measured and combined before mixing ("batching"), and asphalt aggregate is prepared.

The unregulated landfill, in which the radioactive material was placed in 1973, was closed in 1974 by the Missouri Department of Natural Resources (MDNR). Also in 1974, under an MDNR permit, a newer sanitary landfill was opened and now operates in an adjacent area on the West Lake Landfill property. The newer landfill is protected from groundwater contact. The bottom of the new landfill is lined with clay, and a leachate collection system has been installed. Leachate is pumped to a treatment system consisting of a lime precipitation unit followed in series by an aerated lagoon and two unaerated lagoons. The final lagoon effluent is discharged into St. Louis Metropolitan Sewer District sewers.[2]

Ownership

Since 1939, the West Lake Landfill has been owned by West Lake Landfill, Inc., of 13570 St. Charles Rock Road, Bridgeton, Missouri.

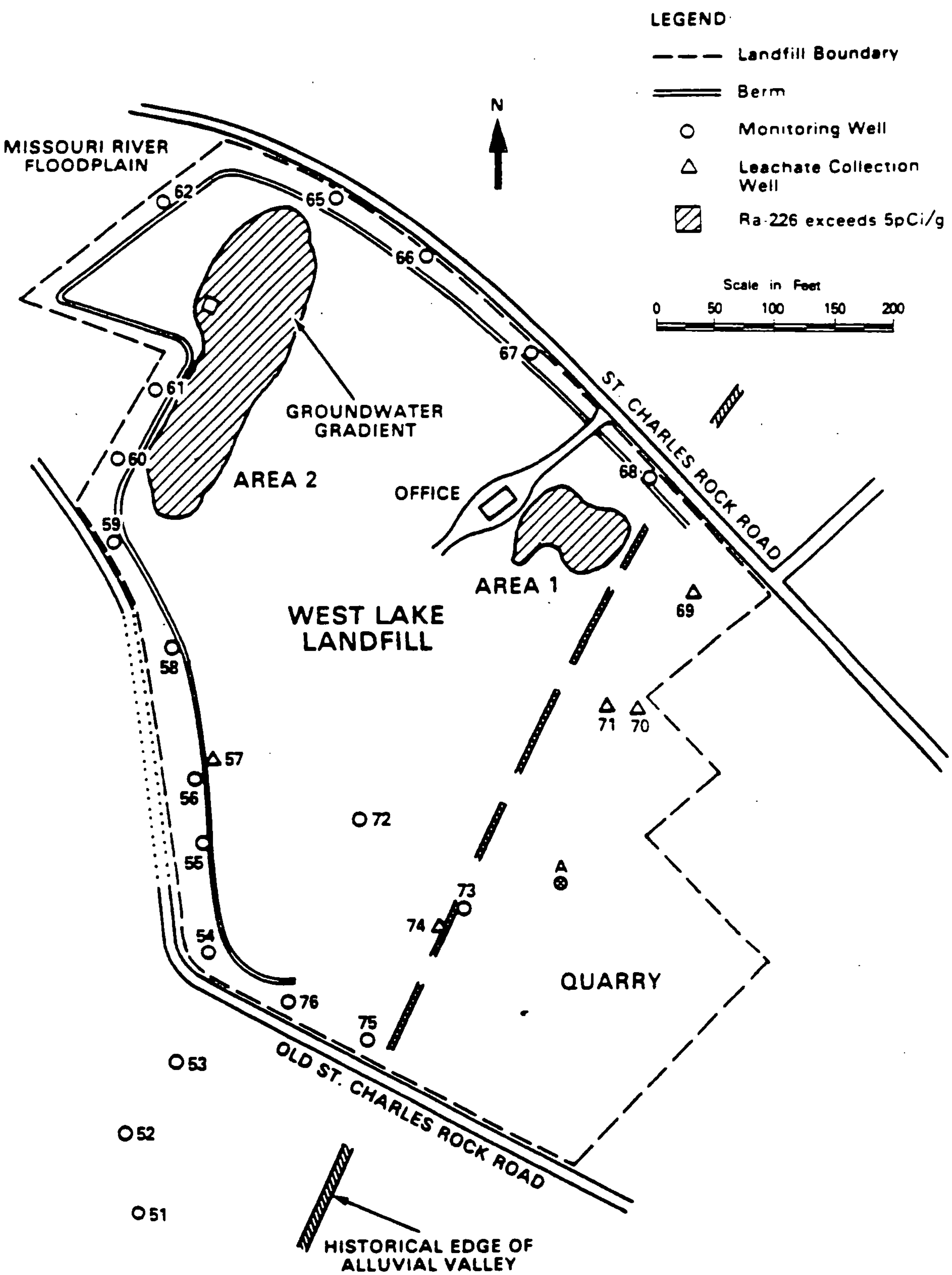

Figure 2 Site Details

Contaminated Areas

Radioactive contamination at the West Lake Landfill has been identified in two separate soil bodies (Figure 2).

The northern area (referred to as Area 2) covers about 13 acres[3] and lies above 16 to 20 feet of landfill debris. The contaminated soil forms a more or less continuous layer from 2 to 15 feet in thickness and consists of approximately 130,000 cubic yards of soil. Some of this contaminated soil is near or at the surface, particularly along the face of the northwestern berm. Beneath the landfill debris, the soil profile consists of 3 to 7 feet of floodplain top soil overlying 30 to 50 feet of sand and gravel alluvium.

The southern area of contamination (Area 1) covers about 3 acres[3] and contains roughly 20,000 cubic yards of contaminated soil. This body of soil is located east of the landfill's main office at a depth of about 3 to 5 feet and is located over a former quarry pit which was filled in with debris. The depth of debris beneath the contaminated soil is unknown but is estimated to be 50 to 65 feet. Limestone bedrock underlies the landfill debris.[2]

Topography

About 75 percent of the landfill site is located on the floodplain of the Missouri River (Figure 2) at about 440 feet above mean sea level (msl). The site topography is subject to change because of the types of activities (e.g., landfilling and quarrying) performed there. However, the areas containing the radioactive waste have their surface at about 470 feet (msl). The surface runoff in the area around the landfill follows several surface drains and ditches that run in a northwest direction and drain into the Missouri River.[2]

Geology

Bedrock beneath the West Lake Landfill consists of limestone that extends downward to an elevation of 190 feet msl. The limestone is dense, bedded, and except for intermittent layers that consist of abundant chert nodules, fairly pure. The Warsaw Formation, which lies directly beneath the limestone, is made up of approximately 40 feet of slightly calcareous, dense shale; this grades into shaley limestone toward the middle of the formation. Bedrock beneath the site dips at an angle of 0.5° to the northeast. Five miles east of the site, the attitude of the bedrock is reversed by the Florissant Dome.[2]

Since groundwater moving through carbonate rocks often creates channels for rapid water flow, the possibility of this occurring in the West Lake Landfill area was considered. Brief observation of the quarry walls at the landfill suggests that some of the limestone has dissolved. In a letter to West Lake Landfill, Inc., the Missouri Department of Natural Resources stated that the fact that grouting was necessary in the quarry area to block water inflow suggests that the limestone is at least somewhat solution weathered.[4] However, in the draft UMC report, the opinion is expressed that the solution activity has apparently been limited to minor widening of joints and bedding planes near the bedrock surface, and that, at depth and when undisturbed, the limestone is fairly impervious.[2] It is not clear whether the views represented by these statements are in conflict.

Soil material in the area may be divided into two categories: Missouri River alluvium and upland loessal soil. This demarcation is shown as the historical edge of the alluvial valley in Figure 2. The division is made on the basis of soil composition, depositional history, and physical properties. The West Lake Landfill lies over this transition zone.[2]

Hydrology

Groundwater flows in the area surrounding the West Lake site through two aquifers: the Missouri River alluvium and the shallow limestone bedrock. Although the limestone is fairly impervious and groundwater flows in most areas from the bedrock into the alluvium, contamination of water in the bedrock aquifer is possible. The base of the limestone aquifer is formed by the relatively impermeable Warsaw shale at an elevation of about 190 feet (msl). This shale layer has been reached, but not disturbed, by quarrying operations. Therefore, the Warsaw shale acts as an aquiclude, making contamination of the deeper limestone unlikely.

The deep Missouri River alluvium, which is under about 10 feet of more-recent alluvium, acts as a single aquifer of very high permeability. This aquifer is relatively homogeneous in a downstream direction and decreases in permeability near the valley walls.

The water table of the Missouri River floodplain is generally within 10 feet of the ground surface, but at many points it is even shallower. At any one time, the water levels and flow directions are influenced by both the river stage and the amount of water entering the floodplain from adjacent upland areas.

Water levels recorded between November 1983 and March 1984 in monitoring wells at the landfill, indicate a groundwater gradient of 0.005 flowing in a N 30°W direction beneath the northern portion of the landfill. This represents the likely direction of leachate migration from the landfill.

Since no other recharge sources exist above the level of the floodplain, the only water available to leach the landfill debris is that resulting from rainfall infiltrating the landfill surface. Because the underlying alluvial aquifer is highly permeable, there will be little "mounding" of water beneath the landfill. Also, the northern portion of the landfill has a level surface, and thus it is likely that at least half of the rainfall infiltrates the surface. The remaining rainfall is lost to evapotranspiration and (to a lesser degree) surface runoff.[2]

No public water supplies are drawn from the alluvial aquifer near the West Lake Landfill. It is believed that only one private well in the vicinity of the landfill is used as a drinking-water supply. This well is 1.4 miles N 35°W of the Butler-type building on the West Lake Landfill.

Because of the extremely low slope of the Missouri River floodplain surface, rain falling on the plain itself generally infiltrates the soil rather than running off the surface. The only streams present on the floodplain are those that originate in upland areas. Drainage patterns on the plain have been radically altered by flood control measures taken to protect Earth City and by drainage of swamps and marshes. Because of the relationship that exists between river level and groundwater level in portions of the floodplain near the river, streams may either lose flow (at low stage) or gain flow (at high stage).

The present channel of the Missouri River lies just under 2 miles west and northwest of the landfill. The Missouri River stage at St. Charles (mile 28) is zero for a water level of 413.7 feet (msl). Average discharge of the Missouri River is 77,338 cubic feet per second.

Water supplies are drawn from the Missouri River at mile 29 for the city of St. Charles, and the intake is located on the north bank of the river. Another intake at mile 20.5 is for the St. Louis Water Company's North County plant. The city of St. Louis takes water from the Mississippi River, which is joined by the Missouri River downstream from the landfill. The intake structures for St. Louis are on the east bank of the river, so that the water drawn is derived from the upper Mississippi.[2]

Demography

Two small residential communities are present near the West Lake Landfill: Spanish Lake Village consists of about 90 homes and is located 0.9 mile south of the landfill, and a small trailer court lies across St. Charles Rock Road, 0.9 mile southeast of the site. Subdivisions are presently being developed 1 to 2 miles east and southeast of the landfill in the hills above the floodplain. Ten or more houses lie east of the landfill, scattered along Taussig Road. The city of St. Charles is located north of the Missouri River, more than 2 miles from the landfill.[2]

Population density on the floodplain is generally less than 26 persons per square mile, but the daytime population (including factory workers) is much greater than the number of full-time residents. Earth City Industrial Park is located on the floodplain 0.9 to 1.2 miles northwest of the landfill. The Ralston-Purina facilities are located 0.2 mile northeast of the Butler-type building at the landfill. Considering that land in this area is relatively inexpensive and that much of it is zoned for manufacturing, industrial development on the floodplain will likely increase.[2]

3 RADIOLOGICAL SURVEYS

From August 1980 through the summer of 1981, the Radiation Management Corporation (RMC), under contract to the NRC, performed an onsite evaluation of the West Lake Landfill[3] to define the radiological conditions at the landfill. The results were utilized in performing this determination regarding whether or not remedial actions should be taken.

The area to be surveyed was divided into 33-foot grid blocks and included the following measurements:

(1) external gamma exposure rates 3.3 feet above the ground surface and beta-gamma count rates 0.4 inch above the surface;

(2) radionuclide concentrations in surface soils;

(3) radionuclide concentrations in subsurface deposits;

(4) total ("gross") activity and radionuclide concentrations in surface and subsurface water samples;

(5) radon flux emanating from surfaces;

(6) airborne radioactivity; and

(7) total activity in vegetation.

External Gamma

The two areas of elevated external (gamma) radiation levels, as they existed in November 1980 at the time of the preliminary RMC site survey, both contained places where levels exceeded 100 μR per hour at 3.3 feet. In Area 2, gamma levels as high as 3000 to 4000 μR per hour were detected. The total areas exceeding 20 μR per hour were about 2 acres in Area 1 and 9 acres in Area 2.[3] (The criterion of 20 μR per hour is derived from the NRC's Branch Technical Position, 46 FR 52061, October 23, 1981, which aims at exposure rates less than 10 μR per hour above background levels; background radiation was taken to be 10 μR per hour also.)

External gamma levels were measured in May and July of 1981. These levels were significantly smaller than the November 1980 values, especially in Area 1, because approximately 4 feet of sanitary fill had been added to the entire area, and an equal amount of construction fill was added to most of Area 2. As a result, only a few thousand square feet in Area 1 exceed 20 μR per hour. In Area 2, the total area exceeding 20 μR per hour decreased by about 10 percent, and the highest levels were about 1600 μR per hour near the Butler-type building.[3]

Surface Soil Analysis

A total of 61 surface soil samples were gathered and analyzed on site for gamma activity. Concentrations of U-238, Ra-226, Ra-223, Pb-211, and Pb-212 were determined for each sample. In all soil samples, only uranium and/or thorium decay chain nuclides and K-40 were detected. Offsite background samples were on the order of 2 pCi per gram for Ra-226. Onsite samples ranged from about 1 to 21,000 pCi Ra-226 per gram and from less than 10 to 2100 pCi U-238 per gram. In samples in which elevated levels of Ra-226 were detected, the concentrations of U-238 were generally one-half to one-tenth of those of Ra-226. In cases of elevated sample activity, daughter products of both U-238 and U-235 were found.[3]

In general, surface activity was limited to Area 2, as indicated by the surface beta-gamma measurements. Only two small regions in Area 1 showed surface contamination; both were near the access road across from the site offices.

In addition to onsite gamma analyses, 12 samples were submitted to RMC's radiochemical laboratories for thorium and uranium radiochemical determinations. The results of these measurements (Table 4 of NUREG/CR-2722) show that all samples contained high levels of Th-230. The ratio of Th-230 to Ra-226 (inferred from Bi-214) generally ranges from 4:1 to 40:1.

Subsurface Soil Analysis

Subsurface contamination was assessed by extensive "logging" of holes drilled through the landfill. Several holes were drilled in areas known to contain contamination, then additional holes were drilled at intervals in all directions until no further contamination was detected. A total of 43 holes were drilled (11 in Area 1 and 32 in Area 2), including 2 offsite wells for monitoring water. All holes were drilled with a 6-inch auger and were lined with 4-inch PVC (polyvinyl chloride) casing.[3]

Each hole was scanned with a 2-inch NaI(Tl) detector and rate meter system for an initial indication of the location of subsurface contamination. On the basis of the initial scans, 19 holes were selected for detailed gamma logging using the intrinsic germanium (IG) detector and multiple channel analyzer. Concentrations of Ra-226, as determined by the IG system, ranged from less than 1 pCi per gram to 22,000 pCi per gram.[3]

It was determined that the subsurface deposits extended beyond areas in which surface radiation measurements exceeded the reference level of 20 μR per hour. The lateral extent of material exceeding 5 pCi Ra-226 per gram, including both surface and buried materials, is shown on Figure 2. The total difference in areas is about 5 acres.

The surface elevations vary by about 20 feet, and the highest elevations occur at locations of more recent fill. Contaminated soil (>5 pCi Ra-226 per gram) is found from the surface to depths as great as 20 feet below the surface. In general, the contamination appears to be a continuous single layer ranging from 2 to 15 feet thick and covering 16 acres.[3]

Nonradiological Analysis

Six composite samples were submitted to RMC's Environmental Chemistry Laboratory for priority pollutant analysis. Five samples were taken from auger holes (one from Area 1 and four from Area 2) and the sixth was taken from sludge from the West Lake Landfill leachate treatment plant. The analysis shows organic solvents present in the Area 2 samples. Positive results were reported for 25 listed organic compounds. Chromium, copper, lead, nickel, and zinc were the predominant elemental priority pollutants detected. The analysis of the sample from the leachate treatment sludge showed that it had smaller pollutant concentrations than the samples from the auger holes.[3]

Chemical analyses of material from the radioactive layer from both areas were also performed by RMC's laboratory. In most cases, elevated levels of barium and lead were found.

Background Radioactivity Measurement

Several offsite locations (within a few miles of the West Lake Landfill) were selected for reference background measurements. Background values were all within the normal range. The gamma exposure rates were 8 and 10.6 μR per hour. Radium-226 concentrations in soil were 2.5 and 2.6 pCi per gram. Radon flux from the ground surface was 0.50 and 0.58 pCi per square meter-second; working level values were 0.0011, 0.0017, and 0.005 WL.[3]

Airborne Radioactivity Analysis

Both gaseous and particulate airborne radioactivity were sampled and analyzed during this study. Since it was known that the buried material consisted partially or totally of uranium ore residues, the sampling program concentrated on measuring radon and its daughters in the air. Two methods were used: the first was a scintillation flask (accumulator) method for radon gas, and the second was analysis of filter paper activity for particulate daughters. A series of grab samples using the accumulator method were taken between May and August of 1981. A total of 111 samples from 32 locations were collected. Measurable radon flux levels ranged from 0.2 pCi per square meter-second in low background areas to 865 pCi per square meter-second in areas of surface contamination.[3]

At three locations, measurements were repeated over a period of 2 months. Significant fluctuations were observed at two locations. The fact that these fluctuations were real and not measurement artifacts was later confirmed by duplicate charcoal canister samples.

A set of 10-minute, high-volume, particulate, air samples was taken to determine both short-lived radon daughter concentrations and long-lived gross alpha activity. The highest levels (0.031 WL) were detected in November 1980, near and inside the Butler-type building. These two samples approximately equal NRC's 10 CFR Part 20, Appendix B, alternate concentration limit of one-thirtieth WL for unrestricted areas. In addition to the routine 10-minute samples, five 20-minute, high-volume, air samples were taken and counted immediately on the IG gamma spectroscopy system to detect the presence of Rn-219 daughters. All samples were taken near surface contamination. Concentrations of Rn-219 daughters ranged from 6×10^{-11} to 9×10^{-10} µCi per cubic centimeter.[3]

Vegetation Analysis

Vegetation samples collected by RMC included weed samples from onsite locations and farm crop samples (winter wheat) near the northwest boundary of the landfill. This location was chosen because water could run off from the fill onto the farm field. No elevated activities were found in these samples.[3]

Water Analysis

A total of 37 water samples were taken by RMC and analyzed for gross alpha and beta activity. Four samples were taken in the fall of 1980 and the remainder in the spring and summer of 1981. One sample was equal to the U.S. Environmental Protection Agency (EPA) gross-alpha-activity standard for drinking water of 15 pCi per liter and that was a sample of standing water near the Butler-type building. Several samples, including all the leachate treatment plant samples, exceeded the EPA drinking water action level for gross beta activity. Subsequent isotopic analyses indicated that the beta activity could be attributed to K-40. None of the offsite samples exceeded either EPA standard.[3]

In 1981, the Missouri Department of Natural Resources collected 41 water samples that RMC analyzed for radioactivity. Of these samples, 5 were background, 10 were onsite surface water, 10 were shallow groundwater standing in boreholes, and 16 were landfill leachate. From these data, background activity is estimated as 1.5 pCi gross alpha activity per liter and 30 pCi gross beta activity per liter. One groundwater sample was at 15 pCi gross alpha per liter, and one surface water sample was 45 pCi per liter. Most of the leachate samples were above 50 pCi beta per liter.[3]

In addition, groundwater samples in 11 perimeter monitoring wells at the West Lake Landfill were taken by the Reitz and Jens Engineering firm on November 15, 1983, and by University of Missouri at Columbia (UMC) personnel on March 21, 1984. In both sampling times, one well, but not the same one, exceeded the EPA's drinking water standard of 15 pCi per liter (18.2 pCi per liter in 1983 and 20.5 pCi per liter in 1984). On May 7 and 8, 1986, Oak Ridge Associated Universities (ORAU) personnel took water samples from 44 perimeter wells; only one (by Old St. Charles Rock Road) with 17 pCi alpha activity per liter exceeded the drinking water standard.[2]

The operators of the landfill, West Lake Landfill, Inc., have an ongoing hydrogeologic investigation of the site, which also involves analyses of monitoring well samples for radioactivity and for priority pollutants.[4]

4 ESTIMATION OF RADIOACTIVITY INVENTORY

Soil sample analyses have shown that the radioactive material in Areas 1 and 2 of the landfill consists almost entirely of natural uranium and its radioactive decay products.

The analyses of soil samples indicate that the naturally occurring U-238 to Th-230 to Ra-226 equilibrium has been altered and that the ratio of Ra-226 to U-238 is on the order of 2:1 to 10:1; the ratio of Th-230 to Ra-226 generally ranges from 4:1 to about 40:1. These ratios are in accord with the history of the radionuclide deposits in the West Lake Landfill, i.e., that they came from the processing of uranium ores. The indicator radionuclides for assessment of the radiological impacts of the material are therefore U-238, Th-230, and Ra-226.

Using the RMC data and averaging the auger hole measurements over the volumes of radioactive material found in Areas 1 and 2, a mean concentration of 90 pCi per gram was calculated for Ra-226.[2] For the ratio of Th-230 to Ra-226, the RMC data[3] range from 4:1 to 40:1; data from samples taken in 1984 along the berm range up to almost 70:1.[5] A further consideration is that the material came from Cotter Corporation's Latty Avenue site (later sold to Futura Coatings, Inc.). Measurements at the Latty Avenue site are variously reported as up to 180:1[6] and about 300:1.[7] Some material of that nature might have been transferred along with the barium sulfate residues. To ensure conservatism in estimating the long-term in-growth of Ra-226, the NRC staff used a ratio of 100:1 to estimate the Th-230 activity. Similarly, the Ra-226:U-238 ratio ranges from 2:1 to 10:1. This ratio is less critical to the radiological aspect of the site and has been estimated to be 5:1 for purposes of calculation.

Using the Th-230:Ra-226 ratio of 100:1, the Th-230 activity is 9000 pCi per gram. If the U-238 concentration (as well as U-234 which would be similarly separated from the ore) is a factor of 5 less than Ra-226, this implies about 18 pCi U-238 per gram. The total mass of radioactive material in the landfill was estimated by visually integrating the volume of radioactive material from graphs and multiplying by an average soil density, resulting in 1.5×10^{11} grams (150,000 metric tons) of contaminated soil.

These numbers indicate that there are about 14 Ci of Ra-226 contained with its decay products in the radioactive material in the landfill. The material also contains about 3 Ci each of U-238 and U-234, and about 1400 Ci of Th-230. These estimates indicate the order of magnitude of the quantities to be dealt with, although the estimate for Th-230 is regarded as conservatively large.

5 APPLICABILITY OF THE BRANCH TECHNICAL POSITION

The NRC has established a Branch Technical Position (BTP) which identifies five acceptable options for disposal or onsite storage of wastes containing low levels of uranium and thorium (46 FR 52061, October 23, 1981).[8]

The concentrations permitted under each disposal option are shown in Table 1.

Table 1 Summary of maximum soil concentrations permitted under disposal options

Source: 46 Federal Register 52061

	Disposal options			
Kind of material	1[a]	2[b]	3[c]	4[d]
Natural thorium (Th-232 + Th-228) with daughters present and in equilibrium. (pCi/g)	10	50	-	500
Natural uranium (U-238 + U-234) with daughters present and in equilibrium. (pCi/g)	10	-	40	200

[a]Based on EPA uranium mill tailings cleanup standards.

[b]Concentrations based on limiting individual doses to 170 mrem per year.

[c]Concentration based on limiting equivalent exposure to 0.02 WL or less.

[d]Concentrations based on limiting individual intruder doses to 500 mrem per year and, in cases of natural uranium, limiting exposure to Rn-222 and other airborne alpha emitters to 0.02 WL or less.

Options 1-4 provide methods under 10 CFR 20.302, for onsite disposal of slightly contaminated materials, e.g., soil, if the concentrations of radioactivity are small enough and other circumstances are satisfactory. The fifth option consists of onsite storage pending availability of an appropriate disposal method.

The material present in the West Lake Landfill is a form of natural uranium with daughters, although the daughters are not now in equilibrium. As mentioned in

Section 4, the average concentration of Ra-226 in the West Lake Landfill wastes is about 90 pCi per gram, which (considered by itself) falls into Option 4 of the BTP since Option 4 criteria are controlled by the Ra-226 content in the wastes (i.e., 200 pCi of U-238 plus U-234 per gram would be accompanied by 100 pCi of Ra-226 per gram). However, because of the large ratio of Th-230 radioactivity to that of Ra-226, the radioactive decay of the Th-230 will increase the concentration of its decay product Ra-226 until these two radionuclides are again in equilibrium. Assuming the ratio of activities of 100:1 used above, the Ra-226 activity will increase by a factor of five over the next 100 years, by a factor of nine 200 years from now, and by a factor of thirty-five 1000 years from now. All radionuclides in the decay chain after Ra-226 (and thus the Rn-222 gas flux) will also be increased by similar multiples. Therefore, the long-term Ra-226 concentration will exceed the Option 4 criteria. Under these conditions, onsite disposal, if possible, will likely require moving the material to a carefully designed and constructed "disposal cell."

6 REMEDIAL ACTION ALTERNATIVES EXAMINED

The evaluation performed by staff of the University of Missouri at Columbia addresses six potential remedial action alternatives, including that of leaving the radioactive material as it is, designated Option A.[2] Option D is the option of excavating the material and shipping it to another site for disposal. Options B, C, E, and F address different approaches to stabilizing the material on the West Lake Landfill site, primarily as temporary remedial actions. Options B, C, and F leave most of the radioactive material where it is but include a variety of measures to contain it and its radon releases and gamma emissions. Option E addresses the approach of constructing an onsite earthen cell, similar to a disposal cell, and moving the radioactive material into it. Under Option F, the radioactive material would be left in place and separate slurry walls would be built downgradient of Areas 1 and 2 to constrain groundwater motion. The estimated costs of Options B through F range from about $370,000 (Option B) to about $5,500,000 (Option F) in 1984 dollars. The estimate for Option D is about $2,500,000, but this does not include the cost of transporting the material to another site and disposing of it there; in the staff's judgment, this could increase the cost by as much as a factor of ten.

Further studies are necessary to determine the most practical approach to disposal of this material.

7 FACTORS CONTRIBUTING UNCERTAINTY

The presence in the landfill of other substances listed as hazardous by the U.S. Environmental Protection Agency raises issues of whether the waste is mixed waste (i.e., both radioactive and chemically hazardous), and whether the landfill must also be disturbed to provide for proper containment of the chemical wastes.

The manner of placing the 43,000 tons of contaminated soil in the landfill caused it to be mixed with additional soil and other material, so that now an appreciably larger amount is involved. If it must be moved, it is not certain whether the amount requiring disposal elsewhere is as little as 60,000 tons or even more than 150,000 tons.

Because the controlling radionuclide (Th-230) has no characteristics that make it easy to measure quantitatively in place, as can be done for the Ra-226 with its decay products, the large but variable ratio of Th-230 to Ra-226 and its decay products makes the delineation of cleanup more difficult. When the ratio is so large (20:1 or more), even a small concentration of Ra-226 in 1988 implies such a large concentration later that it will be necessary to employ more difficult measurement techniques to confirm that the cleanup has been satisfactory.

Any possibility of disposal on site will depend on adequate isolation of the waste from the environment, especially for protection of the groundwater. It is unclear whether the area's groundwater can be protected from onsite disposal at a reasonable cost. This matter will require additional investigation.

8 SUMMARY

In 1973, radioactively contaminated soil amounting to approximately 43,000 tons was deposited in the West Lake Landfill near St. Louis, Missouri. The material originated with decontamination efforts at the Cotter Corporation's Latty Avenue plant. Disposal in the West Lake Landfill was not authorized by the NRC. State officials were not notified of this disposal in 1973 because the landfill was not regulated by the State at the time.

In the period 1980-1981, Radiation Management Corporation (RMC) of Chicago, Illinois, under contract to the NRC, performed a detailed radiological survey of the West Lake Landfill. This survey showed that the radioactive contaminants are in two areas. The northern area (Area 2) covers about 13 acres. The radioactive debris forms a layer 2 to 15 feet thick, exposed in only a small area on the landfill surface and along the berm on the northwest face of the landfill. The southern area (Area 1) contains a relatively minor fraction of the debris covering approximately 3 acres with most of the contaminated soil buried with about 3 feet of clean soil and sanitary fill.

The RMC survey showed that the radioactivity is from the naturally occurring U-238 and U-235 series with Th-230 and Ra-226 as the radionuclides that dominate radiological impact. The survey data indicate that the average Ra-226 concentration in the radioactive wastes is about 90 pCi per gram; the staff estimates the average Th-230 concentration to be about 9000 pCi per gram. Since Ra-226 has been depleted with respect to its parent Th-230, Ra-226 activity will increase in time (for example, over the next 200 years, Ra-226 activity will increase ninefold over the present level). This increase in Ra-226 must be considered in evaluating the long-term hazard posed by this radioactive material.

In addition to RMC's radiological survey, soil and water samples were collected and analyzed by others, including ORAU, UMC, and MDNR. Occasionally a sample of water from a monitoring well exceeds slightly the EPA drinking water standard of 15 pCi gross alpha per liter. Sample analyses for priority pollutants (nonradioactive hazardous substances) show a number of listed pollutants are present. The landfill operators are also conducting a hydrogeological investigation.

From the RMC, UMC, and ORAU surveys conducted at the West Lake Landfill site the staff has made the following findings:

(1) There is a large quantity (on the order of 150,000 tons) of soil contaminated with long-lived radioactive material in the West Lake Landfill. Almost all the radioactivity consists of natural uranium and its radioactive decay products.[3]

(2) Based on the radiological surveys, the radioactive wastes as presently stored at the West Lake Landfill do not satisfy the conditions for Options 1-4 of the NRC's Branch Technical Position (BTP) regarding the disposal of radioactive wastes containing uranium or thorium residues.[8]

(3) A dominant factor for the future is that the average activity concentration of Th-230 is much larger than that of its decay product Ra-226, indicating a significant increase in the radiological hazards in the years and centuries to come.

(4) Some of the radioactive material on the northwestern face of the berm has no protective cover of soil to prevent the spread of contamination and attenuate radiation.

(5) Slightly more than 8 acres of the site exceed 20 μR per hour; the highest reading of 1600 μR per hour occurs near the Butler-type building.

(6) Radon and daughters were measured at 0.031 WL in and around the Butler-type building. This exceeds the BTP value of 0.02 WL.

(7) Based on monitoring-well sample analyses, some low-level contamination of the groundwater is occurring, indicating that the groundwater in the vicinity is not adequately protected by the present disposition of the wastes.

(8) Although these radiological conditions indicate that remedial action is needed, it is unlikely that anyone has received significant radiation exposures from the existing situation.

(9) Sampling results show that chemically hazardous materials have been disposed of adjacent to or possibly mixed with the radioactive material.[3] It is possible that part of the radioactive material has become "mixed" waste.

From these findings and the information developed to date, the NRC staff concludes: (1) measures must be taken to establish adequate permanent control of the radioactive waste and to mitigate the potential long-term adverse impacts from its existing temporary storage conditions and (2) the information developed to date is inadequate for a technological determination of several important issues, i.e., whether mixed wastes are involved, and whether onsite disposal is practical technologically, and, if so, under what alternative methods.

As indicated by the estimates developed by UMC, remedial action will be costly. Further, the investigations to develop the necessary information to resolve major questions and to provide a sound basis for evaluation of the feasibility of disposal alternatives may also be costly. Therefore, it is necessary to determine the way to accomplish the further studies and remedial actions that are needed.

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13. ABSTRACT (200 words or less)

The West Lake Landfill is located near the city of St. Louis in Bridgeton, St. Louis County, Missouri. The site has been used since 1962 for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. This report summarizes the circumstances of the radioactive material in the West Lake Landfill. The radioactive material resulted from the processing of uranium ores and the subsequen[t] sale by the Atomic Energy Commission of the processing residues. Primary emphasis is on the radiological environmental aspects as they relate to potential disposition of the material. It is concluded that remedial action is called for.

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LAIDLAW

M E M O

TO: Scott Schreiber

FROM: Ron Poland

DATE: August 4, 1989

SUBJECT: NRC Report On Bridgeton Radioactive Material

Enclosed is a copy of a report recently issued by the Nuclear Regulatory Commission (NRC) concerning radioactive material at the Bridgeton facility. Although we are not the owners of the radioactive area, the report raises a number of issues which could impact our operation.

The report notes that a portion of the property is zoned residential. Please evaluate this to determine if this applies to any of our current or anticipated operating areas.

The report documents the presence of solvents in the radioactive area. This suggests they may also be present in the portions of the site that we acquired. This is likely to result in a higher level of scrutiny of this site by Missouri DNR and USEPA. We need to upgrade our understanding of site hydrogeology and groundwater quality in order to control this situation. Please outline a program to obtain this information and to assure that we have the appropriate environmental controls in place.

RJP*bc

c.c.: Nigel Guilford
Charlie Leonard

LAI 0293

radioactive area

SITE CHARACTERIZATION AND
REMEDIAL ACTION CONCEPTS FOR
THE WEST LAKE LANDFILL

Docket No. 40-8801

Manuscript Completed: July 1989
Date Published: July 1989

Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

PREFACE

This report has as its basis a characterization of the West Lake Landfill site and evaluation of some potential remedial measures performed primarily by S. K. Banerji, W. H. Miller, J. T. O'Connor and L. S. Uhazy of the University of Missouri-Columbia. The Nuclear Regulatory Commission received the first and second drafts, then titled "Engineering Evaluation of Options for Disposition of Radioactively Contaminated Residues Presently in the West Lake Landfill, St. Louis County, Missouri," in 1984; thus most of the information in this report dates from 1983-1984. However, some more recent data, principally water sampling results, have been added. Waste disposal and other industrial activities have continued on the 200 acre site, as have activities in the vicinity, resulting in changes in details of topography, roads, etc. To provide a more complete view of the radioactive material in the landfill, use has been made of figures from the report titled "Radiological Survey of the West Lake Landfill, St. Louis County, Missouri," NUREG/CR-2722, May 1982.

The remedial action concepts in this report are those proposed by the contractor. Judgments expressed in this report about these concepts are in general those of the contractor, and do not necessarily represent the views of the Nuclear Regulatory Commission. For example, the cost estimates for these concepts are based on radium-226 concentrations whereas the long-term issue is dependent upon the thorium-230 concentrations.

Although some of its information has not been updated since 1984, this report is being released so as to make its collected information available to interested parties.

ABSTRACT

The West Lake Landfill is near the city of St. Louis in Bridgeton, St. Louis County, Missouri. In addition to municipal refuse, industrial wastes and demolition debris, about 43,000 tons of soil contaminated with uranium and its radioactive decay products were placed there in 1973. After learning of the radioactive material in the landfill, the U.S. Nuclear Regulatory Commission (NRC) had a survey of the site's radioactivity performed and, in 1983, contracted, through Oak Ridge Associated Universities (ORAU), with the University of Missouri-Columbia (UMC) to characterize the environment of the site, conduct an engineering evaluation, and propose remedial measures. This report presents a description of the results of the UMC work, providing the environmental characteristics of the site, the extent and characteristics of the radioactive material there, some considerations with regard to potential disposal of the material, and some concepts for remedial measures.

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SUMMARY

In 1973, approximately 7900 metric tons (mt) (8700 short tons) of radioactively contaminated barium sulfate ($BaSO_4$) residues were mixed with about 35,000 mt (39,000 t) of soil, and the entire volume was placed in the West Lake Landfill in St. Louis County, Missouri. This material resulted from decontamination efforts at the Cotter Corporation's Latty Avenue plant where the material had been stored. Disposal in the West Lake Landfill was not authorized by the Nuclear Regulatory Commission (NRC) and was contrary to the disposal location indicated in the NRC records. State officials were not notified of this disposal since the landfill was not regulated by the State at the time. Although the contamination does not present an immediate health hazard, authorities have been concerned about whether this material poses a long-term health hazard to workers and residents of the area and what, if any, remedial action is necessary.

In 1980-81, Radiation Management Corporation (RMC) of Chicago, Illinois, performed a detailed radiological survey of the West Lake Landfill under contract to the NRC (NUREG/CR-2722). This survey was performed to determine the extent of radiological contamination. Before this survey, little was known about the location or activity of radionuclide-bearing soils in the landfill. This survey showed that the radioactive contaminants are in two areas. The northern area (Area 2) covers about 13 acres. The radioactive debris forms a layer 2 to 15 feet thick, exposed in only a small area on the landfill surface and along the berm on the northwest face of the landfill. The southern area (Area 1) contains a relatively minor fraction of the debris covering approximately 3 acres with most of the contaminated soil buried with about 3 feet of clean soil and sanitary fill.

The RMC survey showed that the radioactivity is from the naturally occurring U-238 and U-235 series with Th-230 and Ra-226 as the radionuclides that dominate radiological impact. The survey data indicate that the average Ra-226 concentration in the radioactive wastes is about 90 pCi per gram; the average Th-230

concentration is estimated to be about 9000 pCi per gram. Since Ra-226 has been depleted with respect to its parent Th-230, Ra-226 activity will increase in time (for example, over the next 200 years, Ra-226 activity will increase ninefold over the present level). This increase in Ra-226 must be considered in evaluating the long-term hazard posed by this radioactive material.

In addition to RMC's radiological survey, soil and water samples were collected and analyzed by others, including Oak Ridge Associated Universities (ORAU), and the University of Missouri-Columbia (UMC). Occasionally a sample of water from a monitoring well exceeds slightly the EPA drinking water standard of 15 pCi gross alpha per liter. Sample analyses for priority pollutants (non-radioactive hazardous substances) show a number of listed pollutants are present.

On the basis of radiological surveillance conducted by RMC, UMC, and ORAU, the following areas of concern have been identified:

(1) Radioactive soil is eroding from the northwestern face of the berm, and is being transported off site.

(2) Radon gas had been observed to accumulate to an unacceptable level in the Butler-type building on site. This building has since been removed.

(3) Some degree of radiological contamination has been found in the wells that monitor the perimeter.

(4) Surface exposure rates over much of the contaminated areas are greater than 20 μR/hr.

In March 1983, the NRC through ORAU, contracted with UMC to conduct an engineering evaluation of the site and propose possible remedial measures for NRC's consideration for dealing with the radioactive waste at the West Lake Landfill. The following six remedial options were proposed and evaluated in this study.

- Option A - No remedial action
- Option B - Stabilization onsite with restricted land use

- Option C - Extending the landfill offsite with restricted land use
- Option D - Removal and relocation of the contaminated material to an authorized disposal site
- Option E - Excavation and temporary onsite storage in a trench
- Option F - Construction of a slurry wall to prevent leachate from migrating off site

It is noted that some of the above alternatives for remedial action were initially evaluated with the objective of permanent disposal of the waste at the site.

1 INTRODUCTION

The West Lake Landfill is located in St. Louis County, Missouri, 6 km (3.7 miles) west of Lambert Field International Airport (Figure 1.1) and southwest of St. Charles Rock Road in Bridgeton, Missouri. The site has been used since 1962 for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. In addition, the landfill is an active industrial complex on which concrete ingredients are measured and combined before mixing ("batching"), and asphalt aggregate is prepared. Limestone ceased to be quarried in the spring of 1987.

In 1973, 7900 metric tons [(mt) (8700 short tons)] of radioactively contaminated barium sulfate ($BaSO_4$) residues from uranium and radium processing were mixed with an estimated 35,000 mt (39,000 tons) of soil and deposited in the West Lake Landfill. Previously, this material was located at the Cotter Corporation's Latty Avenue facility in Hazelwood, Missouri, and was removed during decontamination work. It is not known what levels of contamination were already in the soil before the barium sulfate residues were mixed into it. Disposal in the West Lake Landfill was unauthorized and contrary to the disposal location indicated in the U.S. Nuclear Regulatory Commission's (NRC's) records.

Subsequently, the NRC sponsored studies that were directed at determining the radiological status of the landfill. In 1978, an aerial radiological survey revealed two areas within the landfill where the gamma radiation levels indicated radioactive material had been deposited. A more extensive survey was initiated in November 1980 by the Radiation Management Corporation (RMC) under contract to the NRC.

In March 1983, the NRC through Oak Ridge Associated Universities (ORAU) contracted with the University of Missouri-Columbia Department of Civil Engineering to describe the environmental characteristics of the site, conduct an engineering evaluation, and propose possible remedial measures for dealing with the radioactive waste at the West Lake Landfill. In May 1986, ORAU sampled water from

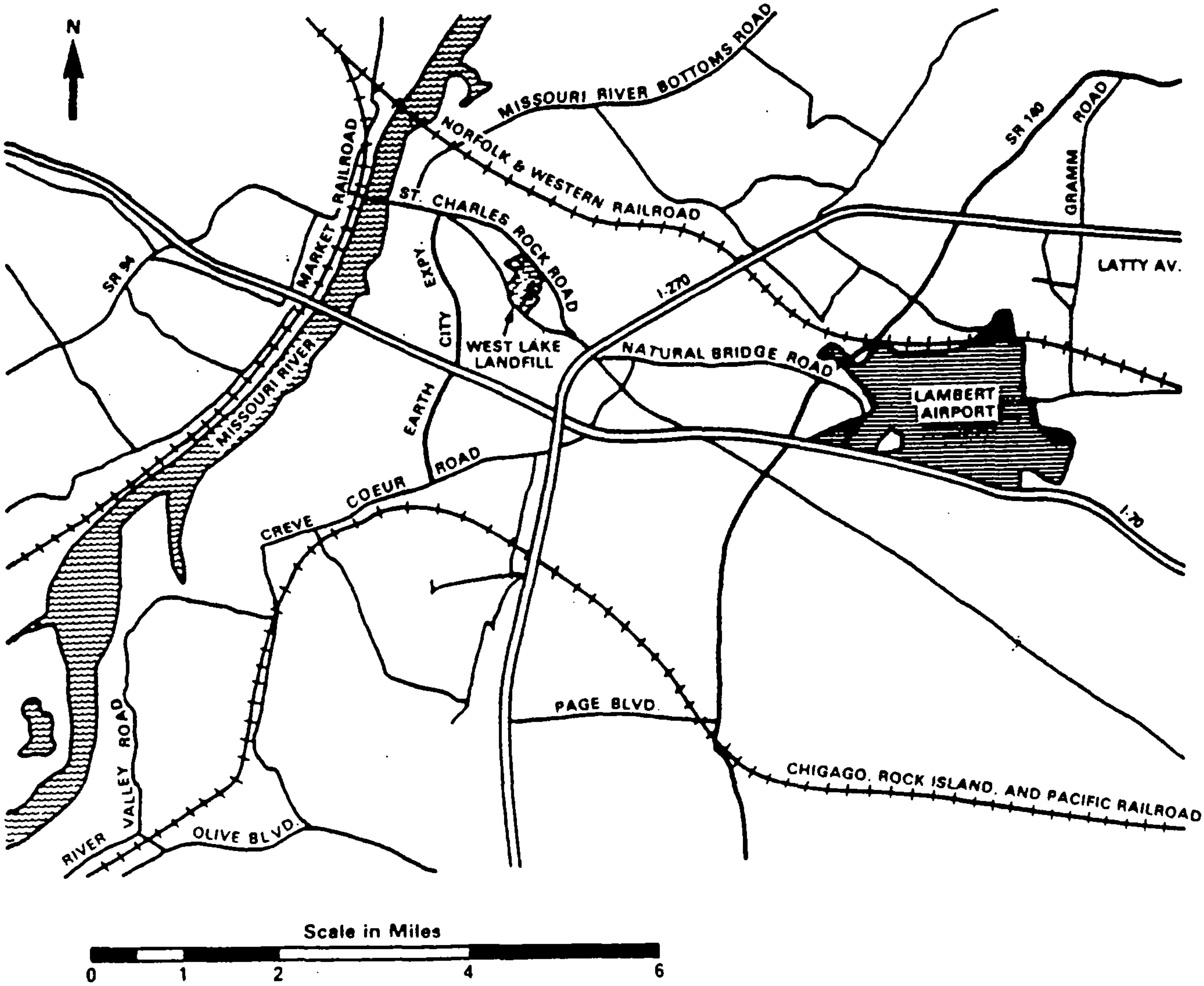

Figure 1.1 Location of West Lake Landfill

wells on and close to the landfill to determine if the radioactive material had migrated into the groundwater.

Information from all these sources forms the basis for this report.

2 SITE DESCRIPTION

This chapter presents a historical and environmental description of the West Lake Landfill site located in St. Louis County, Missouri.

2.1 Location

The 81-hectare (ha) (200-acre) West Lake Landfill property is situated between the St. Charles Rock Road and the Old St. Charles Rock Road in Bridgeton, Missouri. The southeastern and northwestern parts of the landfill abut farmland. Several commercial and industrial facilities are located near the landfill (Figure 2.1). The nearest residential area is a trailer park located approximately 1 km (0.6 mile) to the southeast. A major portion of the landfill (roughly the northern three-fourths of the site) is located on the floodplain, approximately 2 km (1.2 miles) from the Missouri River.

2.2 Zoning

The zoning plan obtained from the Bridgeton Planning and Zoning Department for properties on and adjacent to the landfill is shown in Figure 2.2. A portion of the landfill, including site Area 1, is zoned M-1, which is designated for light manufacturing; the northwest part of the landfill, including Area 2, is zoned as single-family residential (R-1). This R-1 zoning indicates the use to which the land was originally intended. However, the landfill was extended over the land zoned R-1, and the zoning plan was simply not changed to reflect the new usage. Other discrepancies between land use and zoning are found in the nearby Earth City Industrial Park (William Canney, Safety Supervisor of West Lake Landfill, Inc., personal communication, March 1984). The land across St. Charles Rock Road is zoned for light and heavy manufacturing. The remainder of the property surrounding the landfill is zoned residential and business.

2.3 History

The West Lake Landfill was started in 1962 for the disposal of municipal and industrial solid wastes, and to fill in the excavated pits from the quarry operations that had been performed at the site since 1939 (Canney, personal communication, March 1984). In 1974, the landfill was closed by the Missouri Department of Natural Resources (MDNR) (Karch, 1976). A new sanitary landfill, in an area of the West Lake Landfill property which is protected from groundwater contact, now operates under an MDNR permit.

This new part of the landfill was opened in 1974. The bottom is lined with clay and a leachate collection system has been installed. Leachate is pumped to a treatment system consisting of a lime precipitation unit followed in series by an aerated lagoon and two unaerated lagoons. The final lagoon effluent is discharged into St. Louis Metropolitan Sewer District sewers.

The quarrying operation ceased in the spring of 1987 because not enough "good rock" was left at the site.

2.4 Ownership

The West Lake Landfill was owned from 1939 until 1988 by West Lake Landfill, Inc., of 13570 St. Charles Rock Road, Bridgeton, Missouri. Most of the landfill was sold in 1988 to Laidlaw Industries, Inc. The two areas which contain the radioactive material were retained by West Lake Properties as the principal properties of a subsidiary named Rock Road Industries, Inc.

2.5 Contaminated Areas

Radioactive contamination at the West Lake Landfill has been identified in two separate soil bodies (Figure 2.3). Comparisons of radionuclide quantities and of the activity ratios between radionuclides not in secular equilibrium, indicate that the radioactive contamination in the separate soil bodies was derived from the same source, i.e., the Cotter Corporation's former Latty Avenue facility in Hazelwood, Missouri (NRC, NUREG/CR-2722).

The northern area (referred to as Area 2) of contamination shown on Figure 2.3 covers an area of 5.2 ha (13 acres) and lies above 5 to 6 m (16-20 ft) of landfill debris. The contaminated soil forms a more or less continuous layer from 1 to 4 m (3 to 13 ft) in thickness, and amounts to approximately 100,000 m^3 (130,000 yd^3). Some of this contaminated soil is near or at the surface, particularly along the face of the northwestern berm. Beneath the landfill debris, the soil profile consists of 1 to 2 m (3 to 7 ft) of floodplain top soil overlying 10 to 15 m (33 to 50 ft) of sand and gravel alluvium.

The southern area of contamination (referred to as Area 1) shown on Figure 2.3 covers approximately 1.1 ha (3 acres) and contains roughly 15,000 m^3 (20,000 yd^3) of contaminated soil. This body of soil is located east of the landfill's main office at a depth of about 1 m (3 to 5 ft), and is located over a former quarry pit, which was filled in with debris. The depth of debris beneath the contaminated soil is unknown, but is estimated to be 15 to 20 m (50 to 65 ft). Limestone bedrock underlies the landfill debris.

2.6 Topography

About 75% of the landfill site is located on the floodplain of the Missouri River. The site topography is subject to change because of the types of activities (e.g., landfilling and quarrying) performed there. Figure 2.3 shows a contour map of the site as of July 1986. The surface runoff follows several surface drains and ditches which run in a northwest direction and drain into the Missouri River.

2.7 Geology

2.7.1 Bedrock

Bedrock beneath the West Lake Landfill consists of Mississippian age limestone of the Meramacean Series of the St. Louis and Salem formations, which extends downward to an elevation of 58 m (190 ft) mean sea level (msl) (Figure 2.4).*

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*Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, Missouri, Well Log Files.

The limestone is dense, bedded, and fairly pure except for intermittent layers which consist of abundant chert nodules. The Warsaw Formation--also of Mississippian age--lies directly beneath the limestone. The Warsaw is made up of approximately 12 m (38 ft) of slightly calcareous, dense shale; this grades into shaley limestone toward the middle of the formation (Figure 2.4) (Spreng, 1961). Bedrock beneath the site dips at an angle of 0.5° to the northeast. Eight kilometers (5 miles) east of the site, the attitude of the bedrock is reversed by the Florissant Dome; the bedrock dips radially outward from the apex of this dome at a low angle (Martin, 1966).

Since karst (solution) activity often occurs in carbonate rocks, the possibility of its occurrence in the West Lake Landfill area was considered. Brief observation of the quarry walls at the landfill suggests that some solution of the limestone has occurred, but this solution activity has apparently been limited (see Section 2.8.1) to minor widening of joints and bedding planes near the bedrock surface. Although karst activity within the limestone is relatively minor, the upper surface of the bedrock is irregular and pitted as a result of solution (Lutzen and Rockaway, 1971). This alteration of the bedrock surface is greatest beneath the Missouri River floodplain.

2.7.2 Soils

Soil material in this area may be divided into two categories: Missouri River alluvium and upland loessal soil. This demarcation is shown as the historical edge of the alluvial valley in Figure 2.5. The division is made on the basis of soil composition, depositional history, and physical properties. Because the West Lake Landfill lies over this transition zone, the surface material at the site varies considerably from southeast to northwest.

The Missouri River alluvium (Figure 2.6) ranges in thickness from 12 m (40 ft) beneath the landfill site to more than 30 m (100 ft) at mid-valley (Figure 2.7). The upper 3 m (10 ft) of the soil profile consists of organic silts and clays, that have been deposited by the Missouri River during floods.* Below this

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*Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, Missouri, Well Log Files.

surface layer, the soil becomes sandy and grades to gravel at depths greater than 5 to 10 m (16 to 33 ft). Because of the effects of channel scour, which continues to grade the sediment after its initial deposition, the alluvium is fairly homogeneous in a horizontal direction and becomes progressively coarser with depth (Goodfield, 1965). At the edges of the floodplain, the alluvium is not as well graded, and a large amount of fine material is present in the deeper sand and gravel.

The upland loessal soil (Figure 2.8) is generally thinner than the floodplain soil, being usually less than 12 m (39 ft) thick, and was deposited during the age of Pleistocene glaciation. The loess consists of silt-sized particles that were transported by wind and deposited as a blanket over much of Missouri and Illinois. On the hills near the West Lake Landfill, the loess layer may be as much as 24 m (79 ft) thick. It consists of 6 to 9 m (20 to 30 ft) of fairly pure silt (Peoria loess) overlying 6 to 15 m (20 to 49 ft) of clay silt (Roxana loess) (Lutzen and Rockaway, 1971). This loess forms the hills to the southeast of the landfill, but it has long ago been removed from the landfill site and most of the surrounding valleys by erosion. The upper 1 m (3 ft) of the loess has been altered to form a thin soil profile. It should be noted that loess has a vertical permeability which is far greater than its horizontal permeability (Freeze and Cherry, 1979). The total permeability of loess is greatly increased by disturbance. The individual silt grains are generally quite angular, and therefore may not be effectively compacted by the methods commonly used to consolidate clay. The technique most effective in the compaction of loess would employ vibration beneath a surcharge. A relict soil profile from 5 to 10 m (16 to 33 ft) thick lies beneath the loess and directly on top of the bedrock. This soil was formed as a residuum before Pleistocene glaciation and was subsequently covered by the loess blanket. This soil is a highly consolidated clay containing abundant chert fragments (Lutzen and Rockaway, 1971). In addition to the natural geologic properties of the landfill, human disturbance of the soil must also be considered since material within the landfill itself can either limit or facilitate migration of leachate to the Missouri River alluvial aquifer.

In order to prevent downward movement of leachate, it is now a common practice to place a layer of compacted clay beneath sanitary landfills. Newer portions of the landfill (constructed since 1974) have 2 to 3 m (7 to 10 ft) of clay at the base and around the sides. Waste is covered every day with 15 cm (6 in.) of compacted soil; the cover soil presently used is loess (of soil classifications CL and A4) taken from southeast of the landfill (Reitz and Jens, 1983a). If not properly compacted, this material may have a permeability of 0.0001 cm/sec (0.00004 in./sec) or more. It is not known what procedures for compaction, if any, were used at the landfill before 1974 since the site was unregulated in design as well as in materials which were accepted for disposal. It is believed, however, that there is no liner present beneath the northwestern portion of the landfill, and that sanitary (and, possibly, some hazardous) material was placed directly on the original ground surface. Since waste was periodically covered with soil to minimize rodent and odor problems, the landfill probably consists of discrete layers of waste separated by thin soil layers. Both areas containing radioactive material are in these presumably unlined above-ground portions of the landfill.

2.8 Hydrology

2.8.1 Subsurface Hydrology

Groundwater flow in the area surrounding the West Lake site is through two aquifers: the Missouri River alluvium and the shallow limestone bedrock. The base of the limestone aquifer is formed by the relatively impermeable Warsaw shale at an elevation of about 58 m (190 ft) msl (Figure 2.4). This shale layer has been reached, but not disturbed, by quarrying operations. Therefore, the Warsaw shale acts as an aquiclude, making contamination of the deeper limestone very unlikely. The Mississippian limestone beds have very low intergranular permeability in an undisturbed state (Miller, 1977). However, a strong leachate enters the quarry pit at an elevation of about 67 m (220 ft) msl (pt. A on Figure 2.5). This leachate is migrating vertically through more than 30 m (98 ft) of limestone. Explosive detonations associated with quarrying operations will tend to cause fractures to propagate in the quarry wall. These fractures have probably extended less than 10 m (33 ft) into the rock from the quarry face. Beyond this, the rock probably remains undisturbed. These fractures will tend to increase inflow to the quarry pit and allow leachate to percolate downward through the fractured zone. Thus, leachate inflow to the quarry pit is not evidence of large-scale contamination of the limestone aquifer. The only other mechanism by which leachate could travel rapidly through the limestone is by transport through solution channels. Landfill consultants and quarry operators maintain that the limestone is fairly intact (Canney, personal communication, September 1983), and superficial observation of the quarry walls seems to support this conclusion. Since the limestone is fairly impervious, and groundwater flows in most areas from the bedrock into the alluvium, contamination of water in the bedrock aquifer does not appear likely.

The water table of the Missouri River floodplain is generally within 3 m (10 ft) of the ground surface, but at many points it is even shallower. At any one time, the water levels and flow directions are influenced by both the river stage and the amount of water entering the floodplain from adjacent upland areas. A high river stage tends to shift the groundwater gradient to the north, in a direction that more closely parallels the Missouri River. Local rainfall will shift the groundwater gradient to the west, toward the river and along the fall of the ground surface. This is inferred from water levels measured in monitoring wells at the West Lake site. The fact that groundwater levels commonly fluctuate more than does the Missouri River level, indicates that upland-derived recharge exerts a great deal of influence over groundwater flow at the West Lake site. This influence decreases toward the river.

The deep Missouri River alluvium acts as a single aquifer of very high permeability. This aquifer is relatively homogeneous in a downstream direction, and decreases in permeability near the valley walls. The deeper alluvium is covered by 2 to 4 m (7 to 13 ft) of organic silts and clays that may locally contain a large fraction of sand-sized particles. Water levels recorded between November 1983 and March 1984 in monitoring wells at West Lake* indicate a groundwater gradient of 0.005 flowing in a N 30°W direction beneath the northern portion of the landfill. This represents the likely direction of any possible leachate migration from the landfill (Figure 2.5).

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*Data supplied by Reitz and Jens engineering firm, St. Louis, 1984.

The alluvial aquifer recharges from upland areas from three sources: seepage from loess and bedrock bordering the valley, channel underflow of upland streams entering the valley, and seepage losses from streams as they cross the floodplain. Of these sources, streams and their underflow represent the main source of upland recharge to the alluvial aquifer. Streams entering the floodplain raise the water table in a fan-shaped pattern radiating outward from their point of entrance to the plain. In areas where streams are not present, the water slopes downward from the hills, steeply at first and then gently to the level of the free water surface in the Missouri River channel. The situations described above do not take into account the effect of variations in permeability of the shallow soil layer. Aerial photography of the site indicates that a filled backchannel (oxbow lake) type of soil deposit is present along the southwest boundary of the landfill (USDA, 1953). This deposit is probably composed of fine-grained material to the depth of the former channel (6 to 10 m) (20 to 33 ft). This deposit may tend to hamper communication between shallow groundwater on opposite sides of the deposit.

Since no other recharge sources exist above the level of the floodplain, the only water available to leach the landfill debris is that resulting from rainfall infiltrating the landfill surface. Because the underlying alluvial aquifer is highly permeable, there will be little "mounding" of water beneath the landfill. Because the northern portion of the landfill has a level surface it is likely that at least half of the rainfall infiltrates the surface. The remaining rainfall is lost to evapotranspiration and (to a lesser degree) surface runoff. Due to the height of the berm, temporary impoundment of surface runoff is a common occurrence.

No public water supplies are drawn from the alluvial aquifer near the West Lake Landfill. It is believed that only one private well (Figure 2.9) in the vicinity of the landfill is used as a drinking water supply. This well is 2.2 km (1.4 miles) N 35°W of the former Butler-type Building location on the West Lake Landfill. In 1981, analysis showed water in this well to be fairly hard (natural origins) but otherwise of good quality (Long, 1981).

Water in the Missouri River alluvium is hard and usually contains a high concentration of iron and manganese (Miller, 1977). The amount of dissolved solids present in the water of the alluvial aquifer varies greatly; purity increases toward mid-valley where groundwater velocity is greatest. A water sample from a well in the alluvium 3 km (1.9 miles) north of the landfill had a total dissolved solids content of 510 mg/liter and total hardness as $CaCO_3$ of 415 mg/liter. Water in the limestone bedrock generally has a hardness greater than 180 mg/liter as $CaCO_3$ equivalent (Emmett and Jeffery, 1968). Total dissolved solids range from 311 to 970 mg/liter. Water in the limestone aquifer may contain a large amount of sulfate of natural origin (Miller, 1977).

2.8.2 Surface Hydrology

Because of the extremely low slope of the Missouri River flood plain surface, precipitation falling on the plain itself generally infiltrates the soil rather than running off the surface. The only streams present on the floodplain are those that originate in upland areas. Drainage patterns on the plain (Figure 2.9) have been radically altered by flood control measures taken to protect Earth City (Figure 2.1) and by drainage of swamps and marshes. Before these alterations, Creve Coeur Creek passed just south of the landfill, and drained a fairly large area. It has since been redirected to discharge into the Missouri River upstream (south) of St. Charles (Figure 2.9). The old channel still carries some water, and empties into the Missouri River 45.2 km (28 miles) upstream from the confluence with the Mississippi River. Near the landfill, this stream is usually dry. As it crosses the flood plain, the creek passes through shallow lakes which provide a more or less continuous flow to the Missouri River throughout the year. A second stream, Cowmire Creek, crosses the floodplain east of the site. This stream flows northward and joins a backwater portion of the Missouri River at kilometer 35.4 (22 miles). Because of the relationship which exists between river level and groundwater level in portions of the floodplain near the river, these streams may either lose flow (at low stage) or gain flow (at high stage).

The present channel of the Missouri River lies about 3 km (2 miles) west and northwest of the landfill. Early land surveys of this area indicate that 200 years ago the channel was located several hundred meters to the east (toward the landfill) of its present course (Reitz and Jens, 1983b). The Missouri River has a surface slope of about 0.00018 (Long, 1981). River stage at St. Charles [kilometer 45.2 (mile 28)] is zero for a water level of 126.1 m (413.7 ft) msl (Reitz and Jens, 1983a). Average discharge of the Missouri River is 2190 m^3/s (77,300 ft^3/s), with a maximum flow of 2850 m^3/s (101,000 ft^3/s) for the period of April through July, and a minimum flow of 1140 m^3/s (40,300 ft^3/s) in January and December (Miller, 1977). Some average properties of Missouri River water for the period 1951-1970 were: alkalinity = 150 mg/liter as $CaCO_3$ equivalent; hardness = 209 mg/liter as $CaCO_3$ equivalent; pH = 8.1; and turbidity = 694 JTU (Jackson turbidity unit).

Water supplies are drawn from the Missouri River at kilometer 46.6 (mile 29) for the city of St. Charles, and the intake is located on the north bank of the river. Another intake at kilometer 33 (mile 20.5) is for the St. Louis Water Company's North County plant (Reitz and Jens, 1983a).

The city of St. Louis takes water from the Mississippi River, which joins the Missouri River downstream from the landfill. In this segment of the river, the two flow-streams have not completely mixed and the water derived from the Missouri River is still flowing as a stream along the west bank of the Mississippi River channel*. The intake structures for St. Louis are on the east bank of the river so that the water drawn is derived from the upper Mississippi.

2.9 Meteorology

The climate of the West Lake area is typical of the midwestern United States, in that there are four distinct seasons. Winters are generally not too severe and summers are hot with high humidity. First frosts usually occur in October; and freezing temperatures generally do not persist past March. Rainfall is greatest in the warmer months, (about one-quarter of the annual precipitation occurs in May and June) (Figure 2.10) (NRC, 1981). In July and August, thunderstorms are common, and are often accompanied by short periods of heavy rainfall. Average annual precipitation is 897 mm (35.3 in.), which includes the average annual snowfall of 437 mm (17.2 inches snow). Average relative humidity is 68%,

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*Ned Harvey, hydrologist with the USGS, telephone communication, August 1983.

and humidities over 80% are common during the summer. Wind during the period of December through April is generally from the northwest; winds blow mainly from the south throughout the remainder of the year. A compilation of hourly wind observations shows that although the wind resultant is fairly consistent on a monthly basis, the wind actually shifts a good deal and is very well distributed in all directions (Figure 2.11) (NRC, 1981; U.S. Department of Commerce, 1960).

Meteorological data used is from Lambert Field International Airport which is 6 km (3.7 miles) east of the West Lake site. Temperature and precipitation data are also representative of West Lake. However, because of differences in topography between Lambert Field and the site, the actual wind directions at West Lake may be slightly skewed in a NE-SW direction parallel to the Missouri River valley.

2.10 Ecology

The West Lake Landfill is biologically and ecologically diverse. Rather than a single ecological system (e.g., a prairie), it is a mosaic of small habitats associated with

(1) moist bottomland and farmland adjacent to the perimeter berm

(2) poor quality drier soils on the upper exterior and interior slopes of the berm

(3) an irregular waste ground surface associated with the inactive portion of the landfill

(4) aquatic ecosystems present in low spots on the waste ground surface

Generally, the natural systems which are present are limited by operations in the active portion of the landfill and form a corridor along the perimeter berm from near well site 75 (Figure 2.5), on the Old St. Charles Rock Road, clockwise to the main entrance to the landfill near well site 68, along St. Charles Rock

Road. The following observation and descriptions demonstrate the biological variety of these sites.

The flora of the perimeter berm extending from the southwest clockwise to the area of the main entrance to the landfill present a series of contrasts. Along the Old St. Charles Rock Road, the bottom and lower slope of the berm is heavily influenced by the nearby mature silver maple (Acer saccharinum), boxelder (Acer negundo), oak (Quercus), sycamore (Platanus), green ash (Fraximus pennsylvanica), and eastern cottonwood (Populus deltoides) trees associated with the old channel of Creve Coeur Creek. At the corner, between wells 59 and 60 (Figure 2.5), large silver maple and boxelder trees form a dense stand in the moist soils at the base of the berm. The density of these trees declines on this slope extending toward the north (well 61) and the Butler-type Building corner. The extension of this slope toward the northwest is dominated by a dense willow-like thicket in which a few eastern cottonwoods and a hawthorn tree have established. From this northwest corner of the landfill to the eastern limit of the trees between the landfill and St. Charles Rock Road (well 65), the exterior slope of the berm is dominated by dense stands of small and large eastern cottonwoods. This latter occurrence reflects the influence of the well-established eastern cottonwoods and sycamores associated with the permanent pond just north of this site (Figure 2.9). The ground cover along these exterior slopes consists of grasses, forbs, plants common to disturbed areas, seedling cottonwoods, and shrubs. A well-manicured grass groundcover continues from the limit of the trees to the area around the main entrance of the landfill and well 68. This vegetation contributes to the partial stabilization of the steep exterior slopes.

The somewhat drier top and the short, interior slope of the berm, colonized by prairie grasses such as bluestem (Andropogon), blends into the irregular surface of the inactive portion of the landfill. Depressions in this surface allow water to collect and tall grasses, foxtail, and plants characteristic of disturbed areas [e.g., ragweed (Ambrosia), mullein (Verbascum), pokeweed (Phytolacca), cinquefoil (Potentilla), sunflower (Helianthus), and plantain (Plantago)] are replaced by characteristic wetland species [e.g., algae (Spirogyra), cattails (Typha), sedges (Carex), and smartweed (Polygonium)]. Young eastern cottonwoods are established at several of these wet sites.

Generally, the surface vegetation of the inactive landfill gives way to barren waste ground around the Butler-type Building location and the barren terrain associated with recent landfill activities.

Animals were observed associated with these habitats. Cottontail rabbits (Sylvilagus) were encountered most frequently and their fecal pellets were observed on the landfill. Density of fecal material was particularly heavy in the thickets on the exterior slopes of the perimeter berm. In this regard, coyote (Canis latrans) feces containing rabbit fur were observed. Small mammals (rodents) were not seen but could certainly be present in these areas. Large ungulates also were not sighted, but tracks and feces of white-tailed deer indicate that they utilize the landfill.

The only birds observed were a crow (Corvus), several robins (Turdus), and white-crowned sparrows (Zonotrichia leucophrys). This certainly does not reflect the extent to which birds utilize these habitats, for observations were made early in the spring. It is readily apparent that returning migratory passerines would utilize the surface vegetation and berm thickets for nesting, cover, and feed later in the season. It is also possible that waterfowl could utilize the permanent ponds on the landfill and adjacent to St. Charles Rock Road. Twelve scaup (Aythya) and mallards (Anas) were observed on the lagoon which serves as part of the landfill waste water treatment facility.

Small puddles contained characteristic aquatic invertebrates and at least two species of amphibians. Casual examination of these shallow waters revealed three genera of snails (Physa, Lymnaea, Helisoma), an isopod (Asnellus), cyclopoid copepods, and cladocerans. Aquatic insect larvae were not observed; however, this does not rule out their presence. The sighting of a bullfrog tadpole (Rana catesbeiana) and audition of spring peepers (Hyla), indicates these ponds are utilized as breeding sites. No fish were observed in these puddles on the landfill surface; however, a dead gizzard shad (Dorsoma cepedianum) was seen in the pond adjacent to St. Charles Rock Road. The only reptiles seen were the water snake (Nerodia) and the garter snake (Thamnophis).

Although the northwest inactive portion of the landfill is posted with "No Trespassing" signs, it was evident that humans do encroach on these habitats.

Fishing tackle was found tangled in power lines and trees, and spent small-gauge shotgun shells were found on the landfill surface and berms.

2.11 Demographics

The West Lake Landfill is located in the northwestern portion of the city of Bridgeton, in St. Louis County, Missouri. Earth City Industrial Park is located on the floodplain 1.5 to 2 km (0.9 to 1.2 miles) northwest of the landfill. Population density on the floodplain is generally less than 10 persons per square kilometer (26 persons per square mile); and the daytime population (including factory workers) is much greater than the number of full-time residents.

Major highways in the area include Interstate 70 (I-70) and Interstate 270 (I-270), which meet south of the landfill at Natural Bridge Junction (Figure 1.1). The Earth City Expressway and St. Charles Rock Road lie, respectively, west and east of the landfill. The Norfolk and Western Railroad passes about 1 km (0.6 mile) from the northern portion of the landfill (Figure 1.1). Lambert Field International Airport is located 6 km (3.7 miles) east of the West Lake Landfill.

In addition to factories at Earth City, plants are operated by Ralston-Purina and Hussman Refrigeration across St. Charles Rock Road. The employees of these two plants probably comprise the largest group of individuals in close proximity to the contaminated areas for significant periods of time. The Ralston-Purina facilities are located 0.4 km (0.2 mile) northeast of the Butler-type Building location at the landfill. Considering that land in this area is relatively inexpensive and that much of it is zoned for manufacturing, industrial development on the floodplain will likely increase in the future.

Two small residential communities are present near the West Lake Landfill. Spanish Lake Village consists of about 90 homes and is located 1.5 km (0.9 mile) south of the landfill, and a small trailer court lies across St. Charles Rock Road, 1.5 km (0.9 mile) southeast of the site (Figure 2.1). Subdivisions are presently being developed 2 to 3 km (1.2 to 1.9 miles) east and southeast of the landfill in the hills above the floodplain. Ten or more houses lie east of the landfill scattered along Taussig Road. The city of St. Charles is located north of the Missouri River at a distance greater than 3 km (1.9 miles) from the landfill.

Areas south of the West Lake Landfill are zoned residential; areas on the other sides are zoned for manufacturing and business (Figure 2.2). Most of the landfill is zoned for light manufacturing (M-1). However, approximately 0.3 km^2 (0.12 mi^2) of the northern portion of the landfill is zoned for residential use; this includes the contaminated area around the Butler-type Building site. The field northwest of the landfill between Old St. Charles Rock Road and St. Charles Rock Road is under cultivation. Trends indicate that the population of this area will increase, but the land will probably be used primarily for industrial facilities.

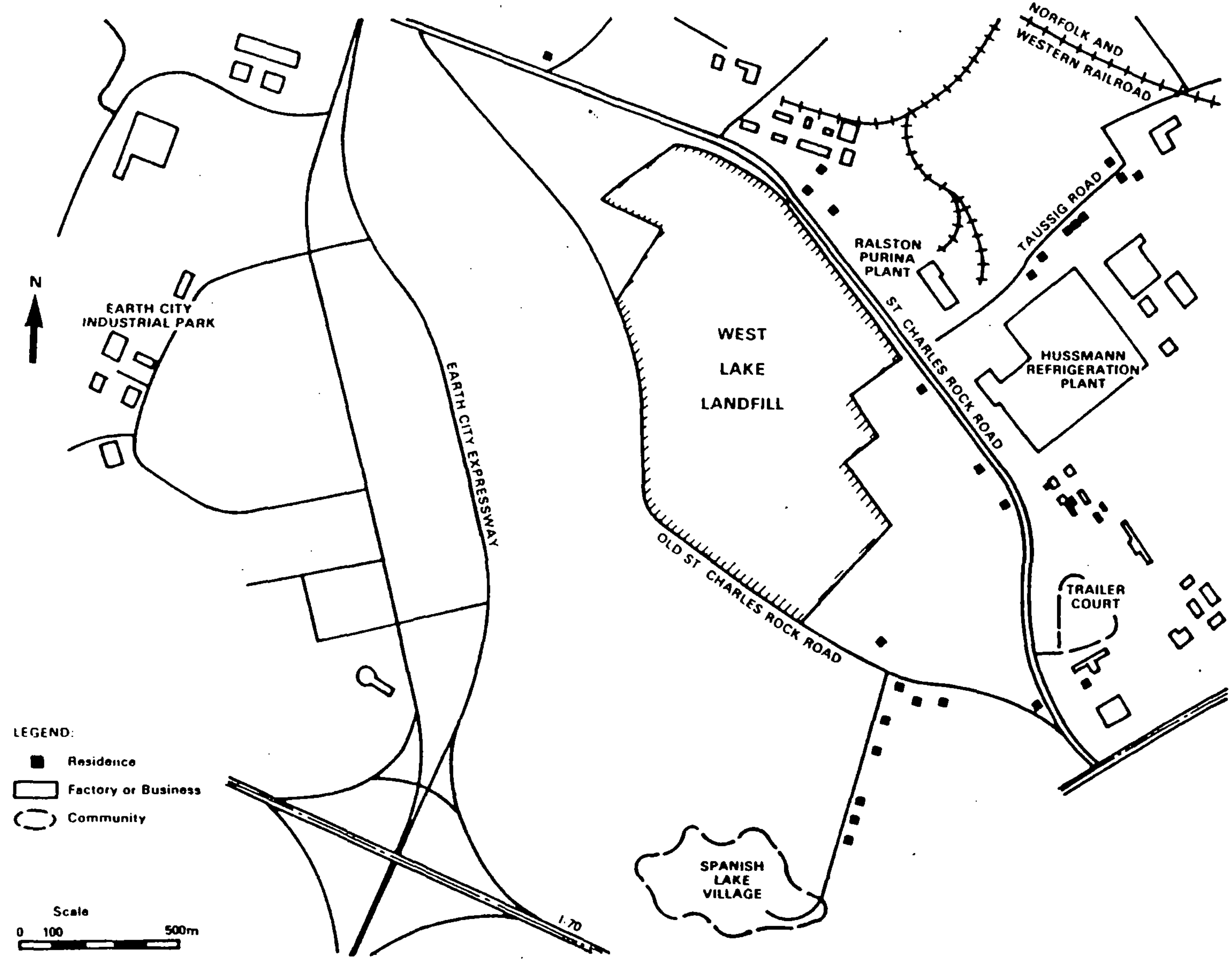


Figure 2.1 Land use around West Lake Landfill site

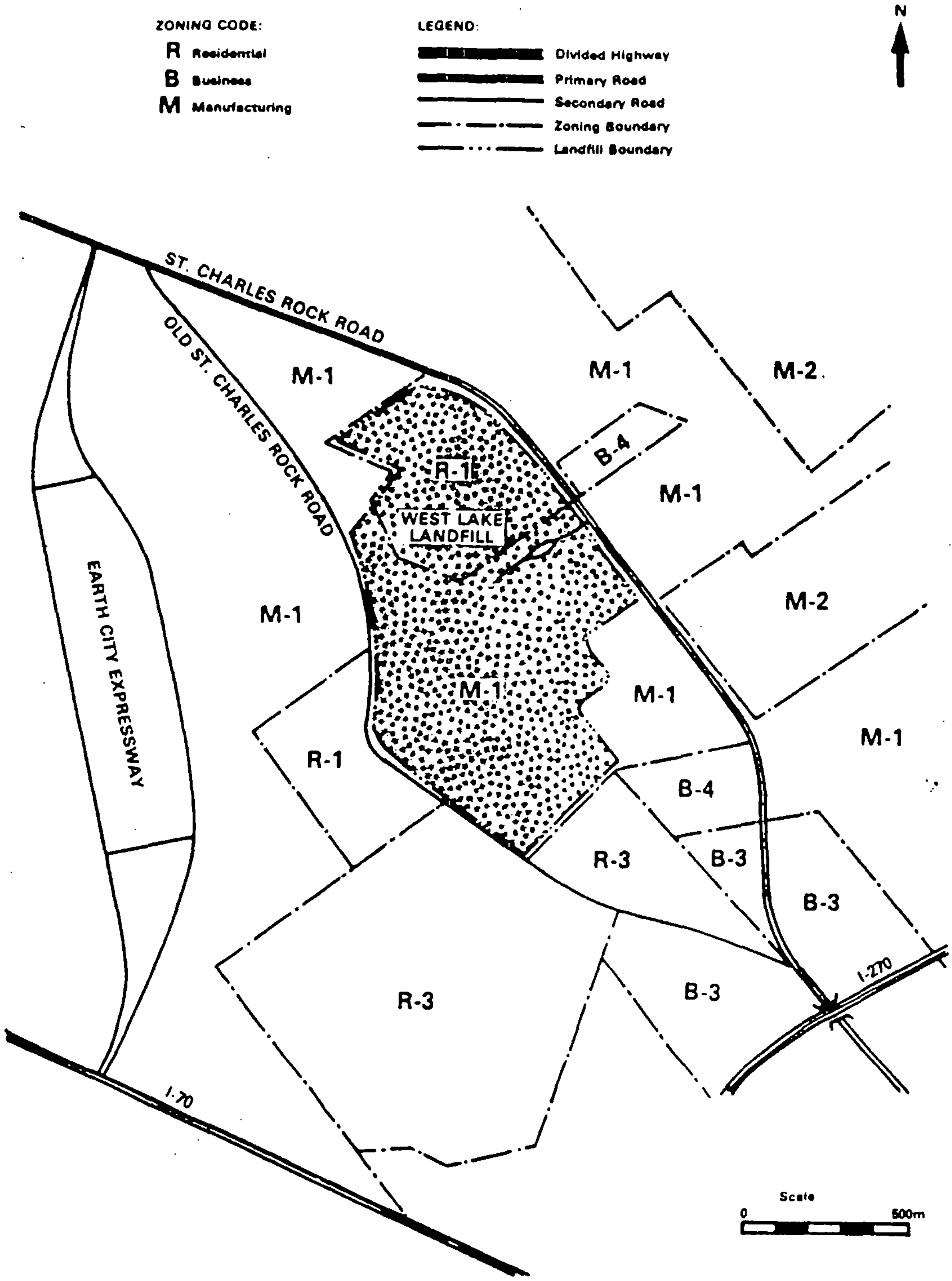


Figure 2.2 Zoning plan of West Lake area (June 1984)

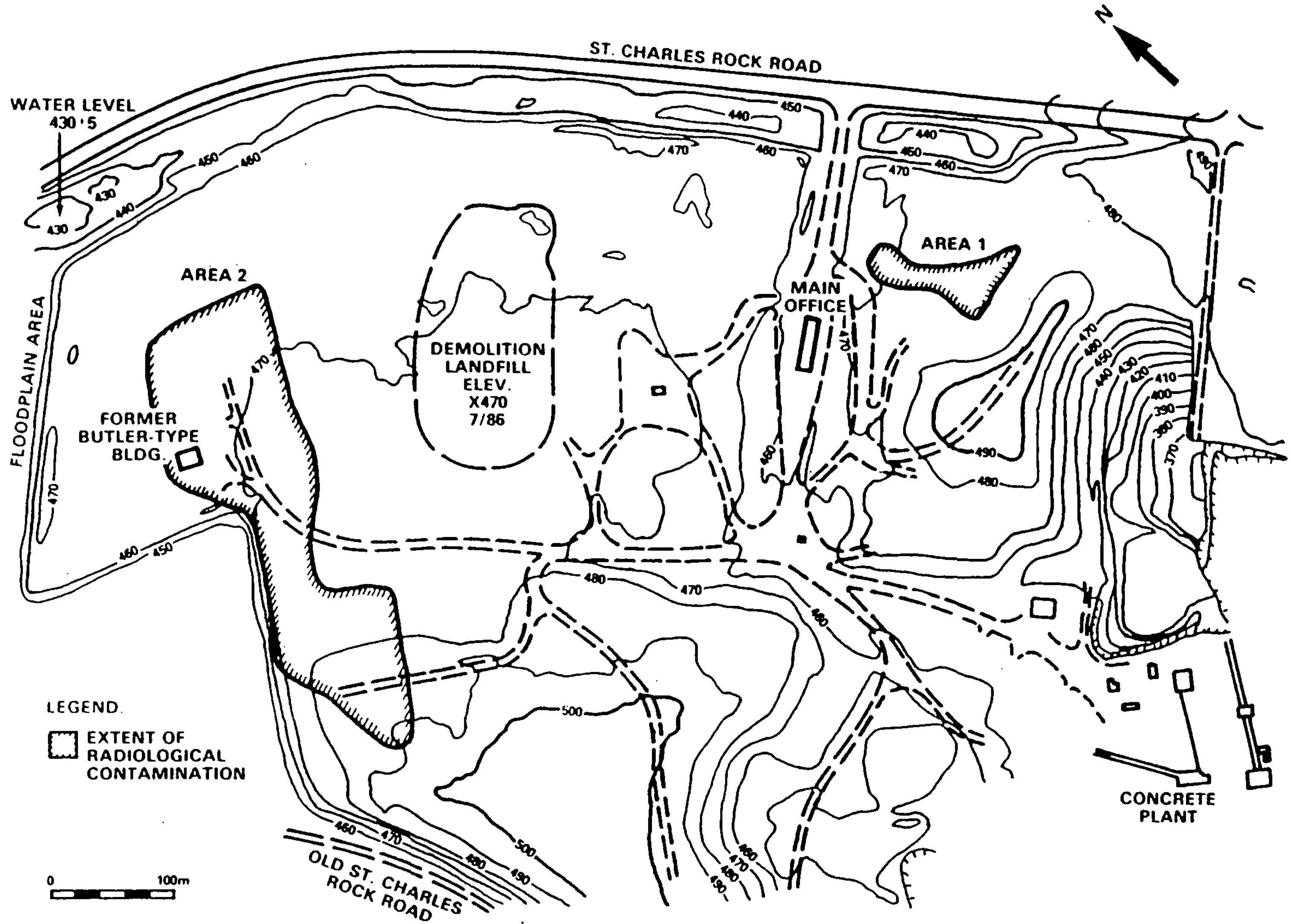


Figure 2.3 Site topography and extent of contamination.

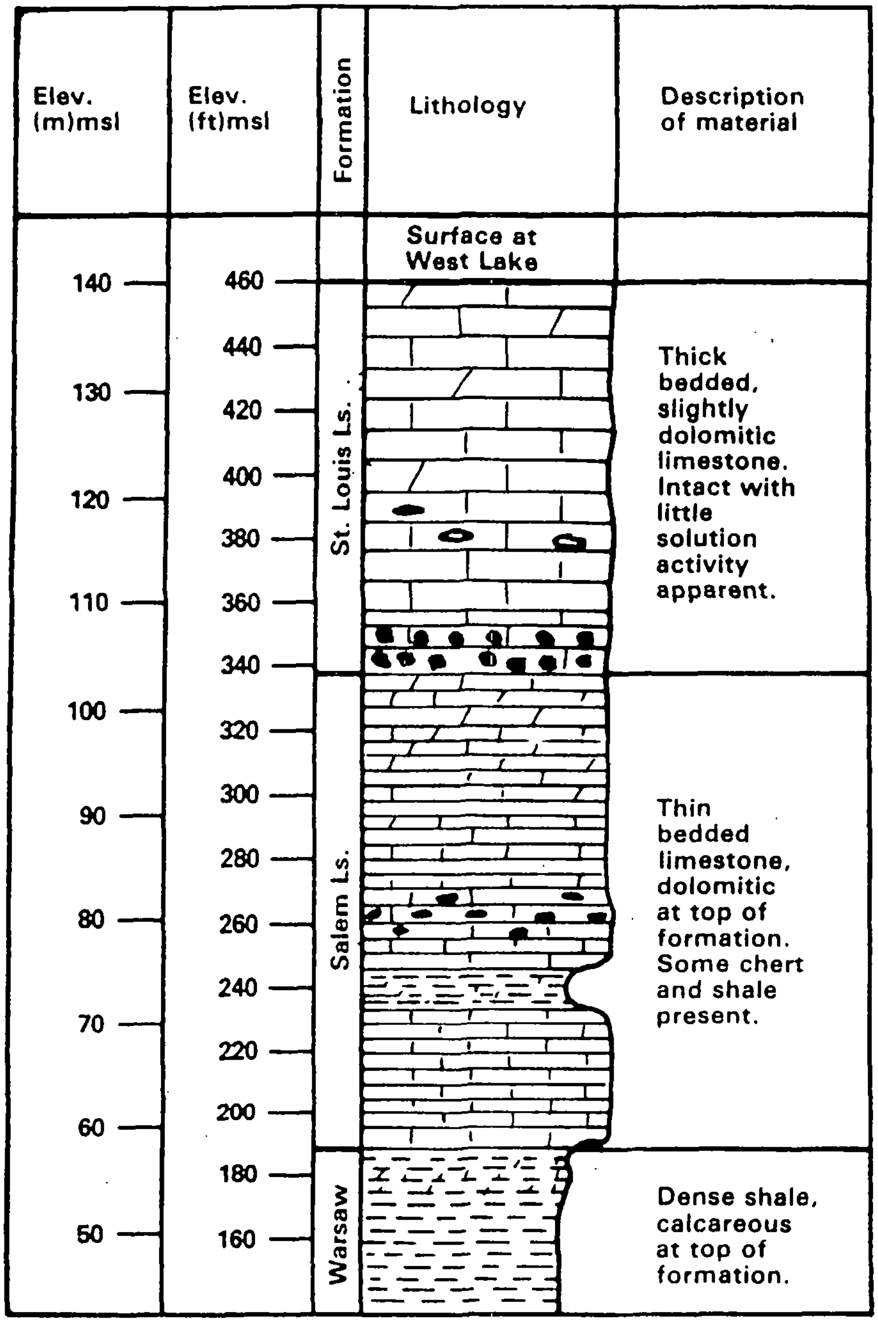


Figure 2.4 Bedrock stratigraphy

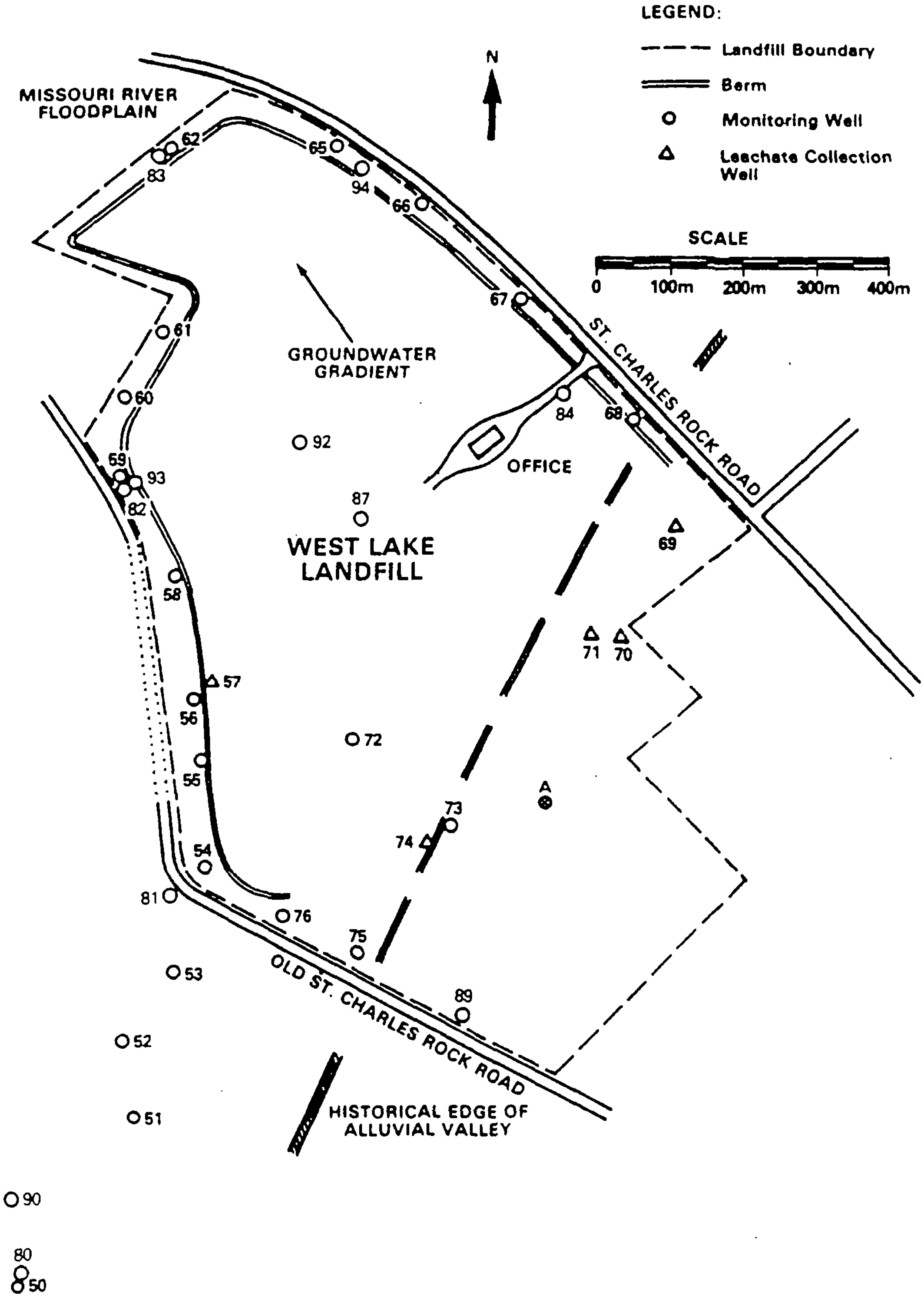


Figure 2.5 Location of monitoring wells

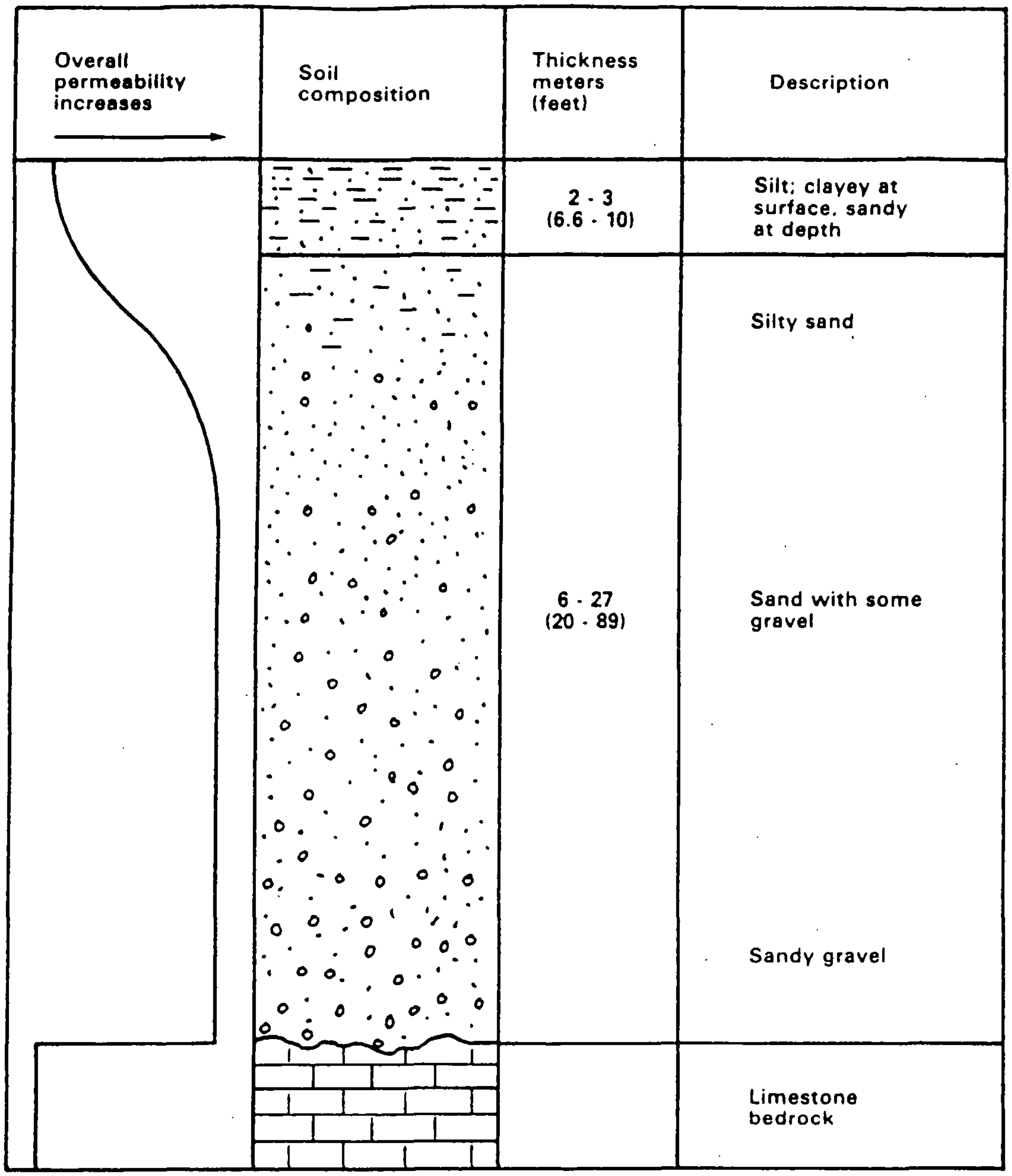


Figure 2.6 Soil profile of river alluvium

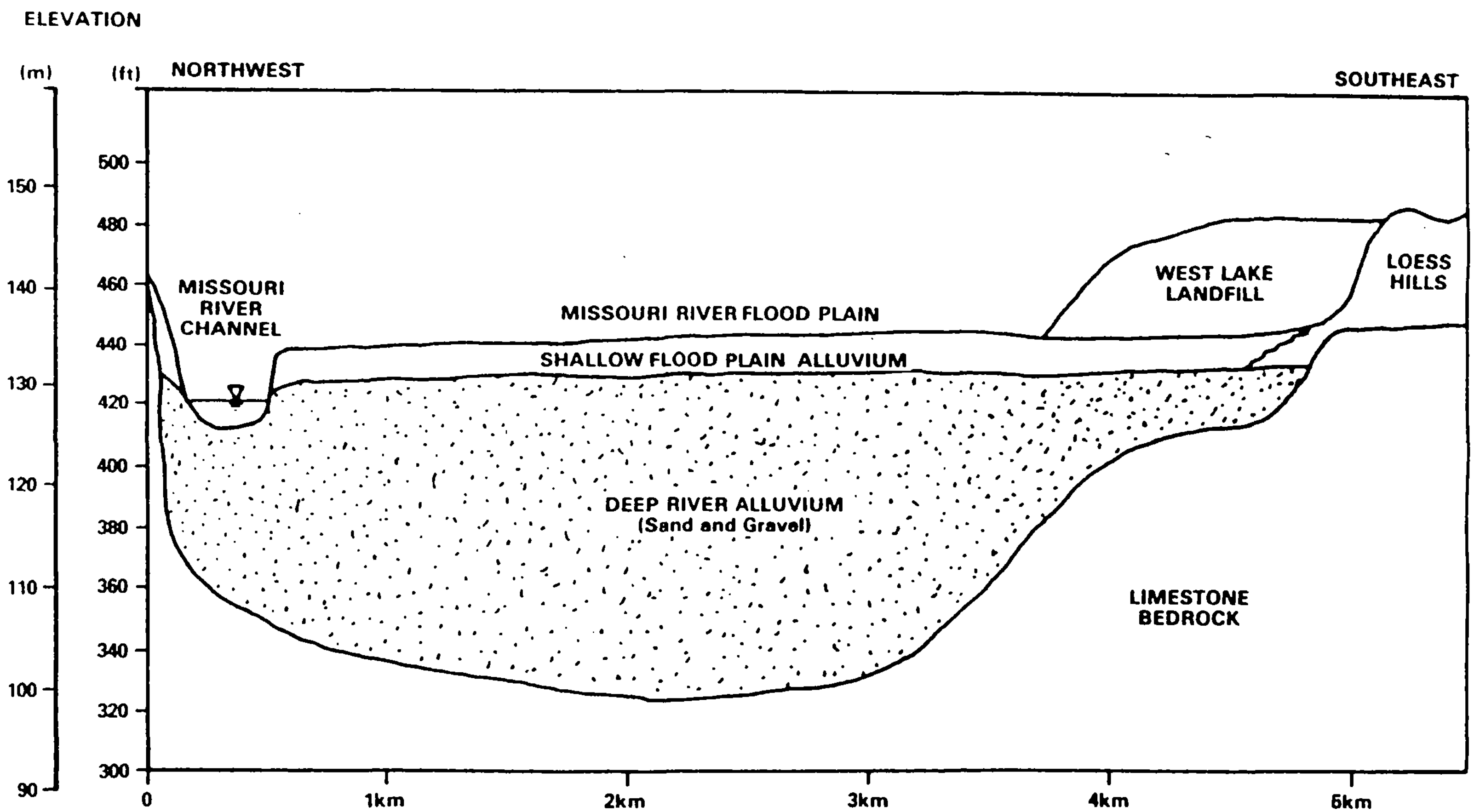


Figure 2.7 Cross-section of Missouri River alluvial valley

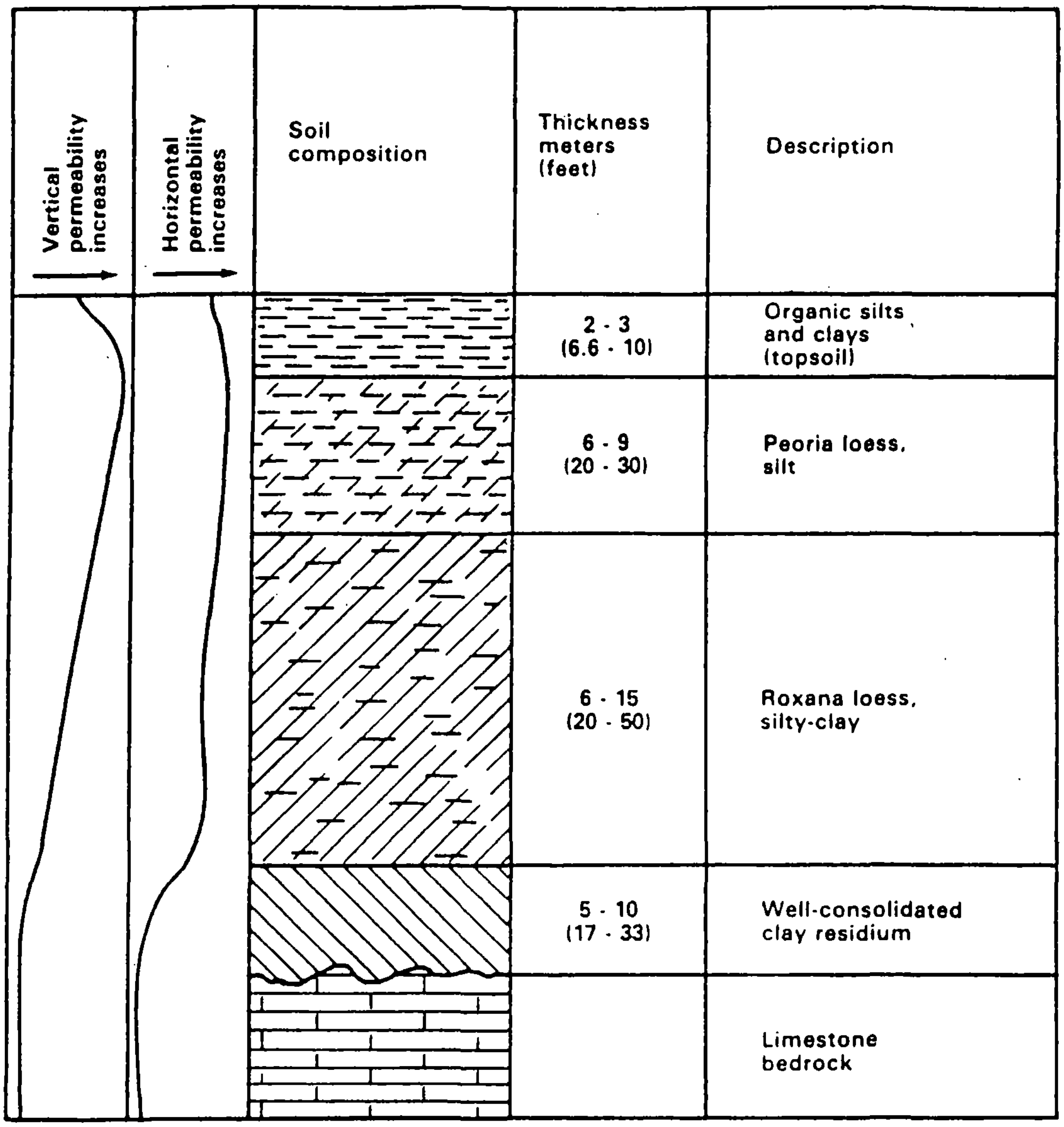


Figure 2.8 Soil profile of upland loessal soil

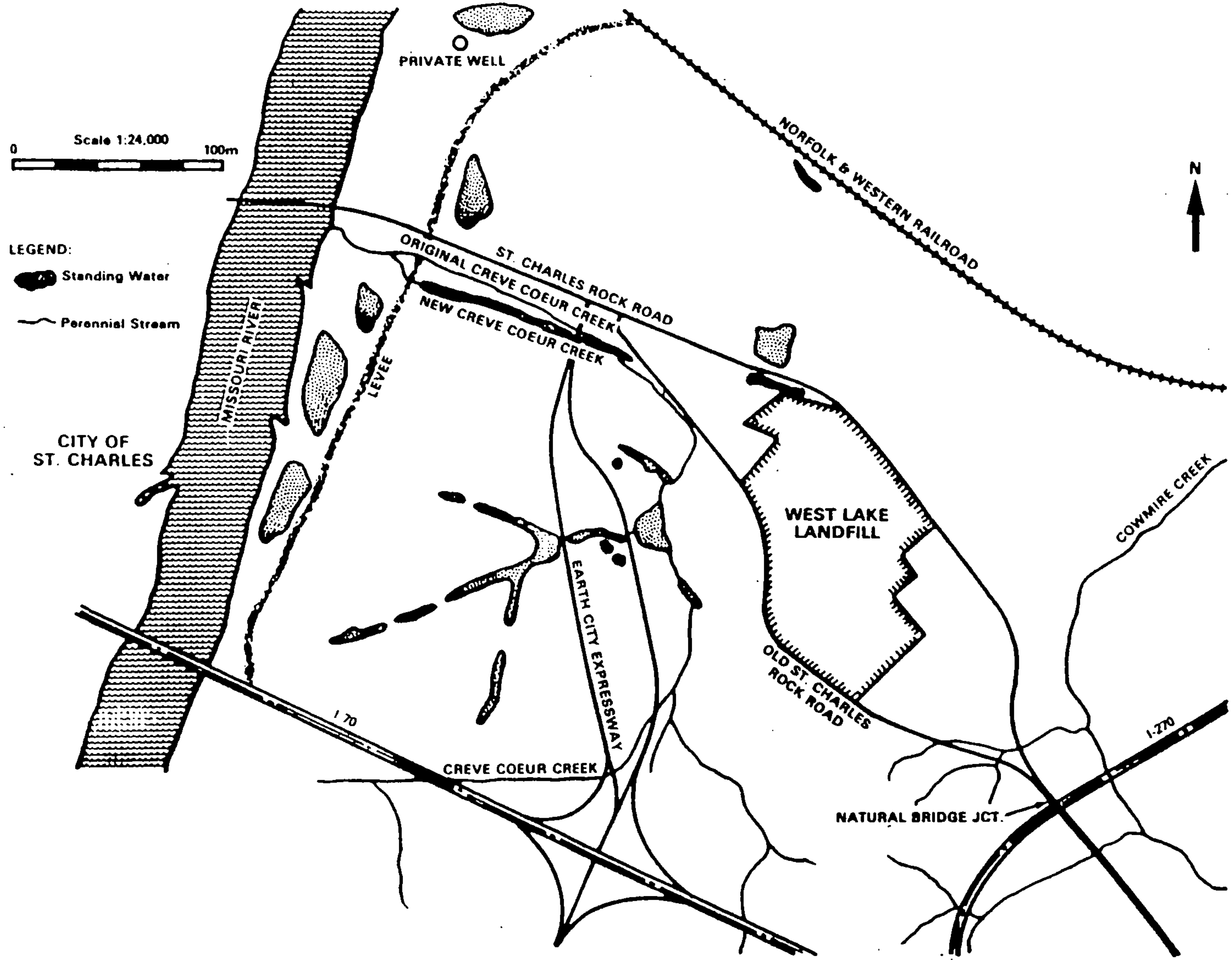


Figure 2.9 Surface hydrology of West Lake area

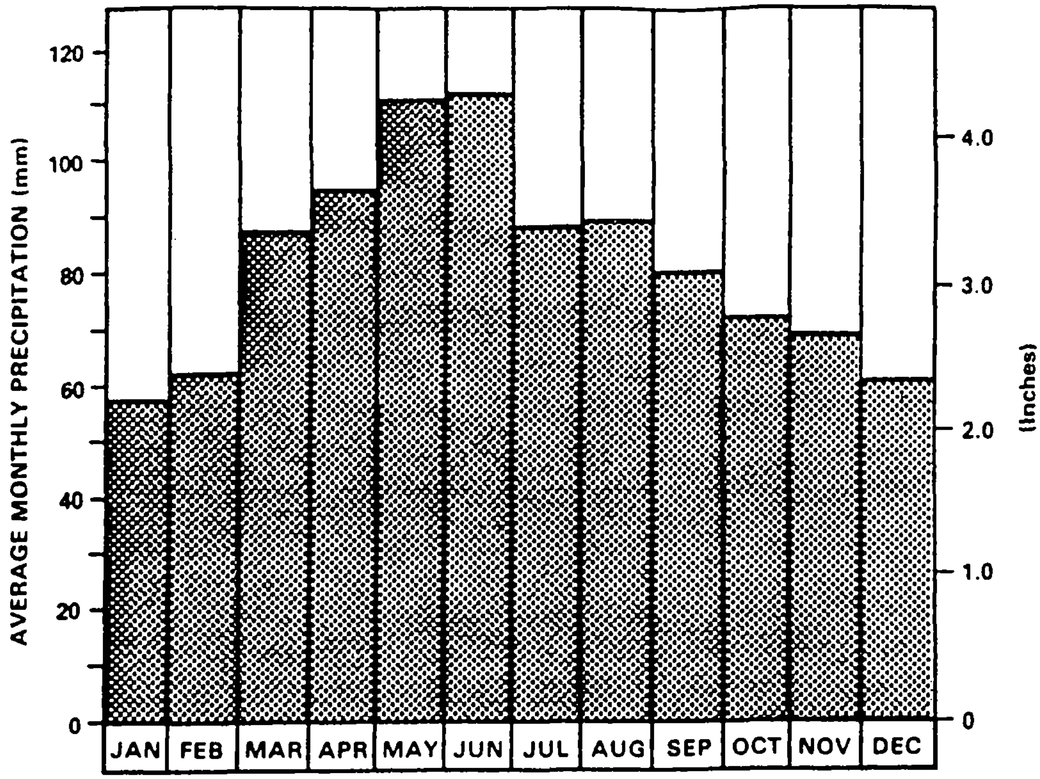
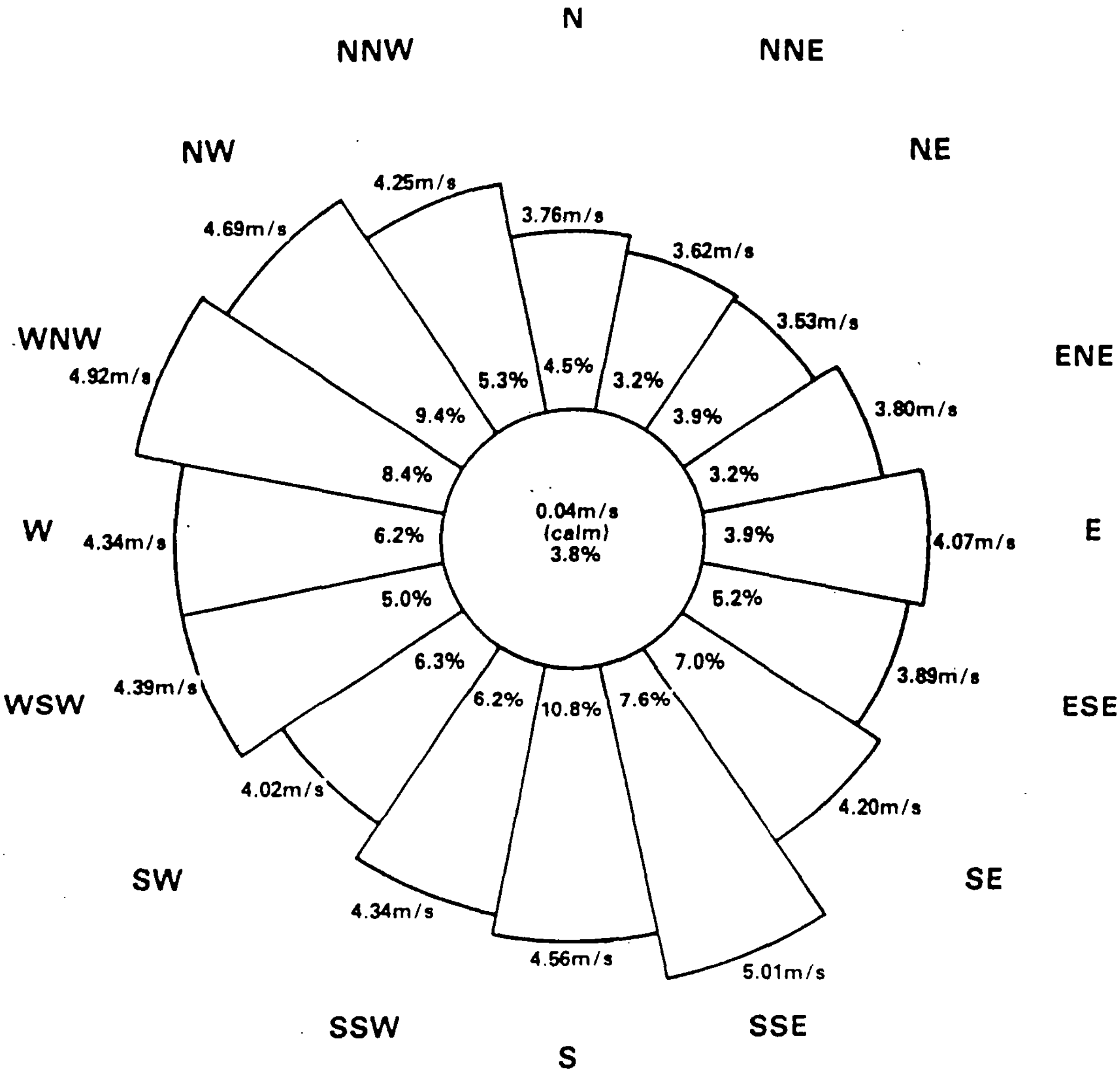


Figure 2.10 Average monthly precipitation at Lambert Field International Airport



Wind rose is for Lambert Field International Airport, Hazelwood, Missouri, and shows the percentage of hourly observations in each direction along with the average speed in that direction; for example: wind blew from the north 4.5% of the time at an average speed of 3.76 m/s.

Figure 2.11 Wind distribution for West Lake area

3 RADIOLOGICAL CHARACTERIZATION OF THE SITE

3.1 Radiological Surveillance

Approximately 43,000 mt (47,000 tons) of contaminated soil were reported to have been disposed of in the landfill. A fly-over radiological survey performed for the NRC in 1978 identified two areas of contamination at the West Lake Landfill.

Subsequently, from August 1980 through the summer of 1981, the Radiation Management Corporation (RMC), under contract to the NRC, performed an onsite evaluation of the West Lake Landfill (NRC, NUREG/CR-2722). The purpose of this survey was to clearly define the radiological conditions at the landfill. The results were to be utilized in performing an engineering evaluation to determine if remedial actions should and could be taken.

The area to be surveyed was divided into 10-m (33-ft) grid blocks and included the following measurements:

(1) external gamma exposure rates 1 m (3.3 ft) above the surfaces and beta-gamma count rates 1 cm (0.4 in.) above surfaces

(2) radionuclide concentrations in surface soils

(3) radionuclide concentrations in subsurface deposits

(4) gross activity and radionuclide concentrations in surface and subsurface water samples

(5) radon flux emanating from surfaces

(6) airborne radioactivity

(7) gross activity in vegetation

3.2 Survey Results

External Gamma

Figure 3.1 shows the two areas of elevated external radiation levels as they existed in November 1980, at the time of the preliminary RMC site survey. As can be seen, both areas contained locations where levels exceeded 100 μR/hr at 1 m (3.3 ft). In Area 2, gamma levels as high as 3000 to 4000 μR/hr were detected. The total areas exceeding 20 μR/hr were about 1.2 ha (3 acres) in Area 1 and 3.6 ha (9 acres) in Area 2.

External gamma levels measured in May and July of 1981 decreased significantly, especially in Area 1, because approximately 1.2 m (4 ft) of sanitary fill was added to the entire area and an equal amount of construction fill was added to most of Area 2. As a result, only a few hundred square meters (a few thousand square feet) in Area 1 exceed 20 μR/hr. In Area 2, the total area exceeding 20 μR/hr decreased by about 10%, and the highest levels were about 1600 μR/hr, near the location of the Butler-type building.

Surface Soil Analyses

A total of 61 surface soil samples were gathered and analyzed on site for gamma activity. Samples were normally stored 10 to 14 days to allow ingrowth of radium daughters. Concentrations of U-238, Ra-226 (from Pb-214 and Bi-214), Ra-223, Pb-211, and Pb-212 were determined for each sample. Surface soil samples are located in Figures 3.2 and 3.3.

In all soil samples, only uranium and/or thorium decay chain nuclides and K-40 were detected. Offsite background samples were on the order of 2 pCi/g Ra-226. Onsite samples ranged from about 1 to 21,000 pCi/g Ra-226, and from less than 10 to 2100 pCi/g U-238. In those cases where elevated levels of Ra-226 were detected, the concentrations of U-238 were generally anywhere from a factor of 2 to 10 lower. In cases of elevated sample activity, daughter products of both U-238 and U-235 were found.

In general, surface activity was limited to Area 2, as indicated by surface beta-gamma measurements. Only two small regions in Area 1 showed contamination; both were near the access road across from the site offices.

In addition to onsite gamma analyses, 12 samples were submitted to RMC's radiochemical laboratories for thorium and uranium radiochemical determinations. The results show all samples contain high levels of Th-230. The ratio of Th-230 to Ra-226 (Bi-214) is about 20 to 1.

Subsurface Soil Analysis

Subsurface contamination was assessed by extensively "logging" holes drilled through the landfill. Several holes were drilled in areas known to contain contamination, then additional holes were drilled at intervals in all directions until no further contamination was encountered. A total of 43 holes were drilled, 11 in Area 1 and, in Area 2, 32 including 2 nearby offsite wells for monitoring water. All holes were drilled with a 6-in. auger and lined with 4-in. PVC (polyvinyl chloride) casing. The location of these auger holes is shown in Figures 3.4 and 3.5.

Each hole was scanned with an NaI(Tl) detector and rate meter system for an initial indication of the location of subsurface contamination. On the basis of the initial scans, 19 holes were selected for detailed gamma logging using the intrinsic germanium (IG) detector and multiple channel analyzer.

The results of the NaI(Tl) counts and IG analyses show concentrations of Bi-214, as determined by the IG system, ranged from less than 1 to 19,000 pCi/g. For those holes where both NaI(Tl) counts and IG counts were made, a good correlation between gross NaI(Tl) counts and Ra-226 concentrations, as determined by in situ analysis of the daughter Bi-214 by the IG system, was found.

It was determined that the subsurface deposits extended beyond areas where surface radiation measurements exceeded 5 pCi/g. The approximate area of subsurface contamination compared to the area of elevated surface radiation levels shows a total difference in areas of 2 ha (5 acres).

The variations of contamination with depth for Areas 1 and 2 are shown in Figure 3.6. As can be seen, the surface elevations vary by about 6 m (20 ft), and the highest elevations occur at locations of fresh fill. Contamination (>5 pCi/g Ra-226) in several areas is found to extend from the surface to appreciable depths, about 6 m (20 ft) below the surface in two cases. In general, the subsurface contamination appears to be a continuous single layer, ranging from 0.6 to 4.6 m (2 to 15 ft) thick, located between elevations of 139 to 144 m (455 to 480 ft) and covering 6.5 ha (16 acres) total area.

In Figures 3.7 and 3.8, representations of the subsurface deposits are provided on the basis of auger hole measurements. These representations are consistent with the operating history of the site, which suggests that the contaminated material was moved onto the site and spread as cover over fill material. Thus, one would expect a fairly continuous, thin layer of contamination, as indicated by survey results.

Nonradiological Analysis

Six composite samples were submitted to RMC's Environmental Chemistry Laboratory for priority pollutant analysis. Five samples were taken from auger holes (one from Area 1 and four from Area 2) and the sixth from the West Lake leachate treatment plant sludge. The results indicate a significant presence of organic solvents in Area 2 samples. The results of the leachate sludge analysis were not as high as any of the soil samples.

A chemical analysis of radioactive material from both areas was also performed by RMC's laboratory. Results show elevated levels of barium and lead in most cases.

Background Radioactivity Measurement

Various offsite locations were selected for reference background measurements. The results of these measurements were within the normal range.

Airborne Radioactivity Analyses

Both gaseous and particulate airborne radioactivity were sampled and analyzed during this study. Since it was known that the buried material consisted partially or totally of uranium ore residues, the sampling program concentrated on measuring radon and its daughters in the air. Two methods were used: the first was a scintillation flask method for radon gas and the second was analysis of filter paper activity for particulate daughters.

A series of grab samples using the accumulator method were taken between May and August of 1981. A total of 111 samples from 32 locations was collected. Measurable radon flux levels ranged from 0.2 pCi/m^{2}s in low background areas to 865 pCi/m^{2}s in areas of surface contamination.

At three locations, repetitive measurements were made over a period of 2 months. These results are plotted in Figure 3.9. As can be seen, significant fluctuations were observed at two locations. The fact that these fluctuations were real and not measurement artifacts was later confirmed by duplicate charcoal canister samples, as described below.

A total of 35 charcoal canister samples was gathered at 19 locations over a 3-month period. The results show levels ranging from 0.3 pCi/m^{2}s to 613 pCi/m^{2}s. On 24 different occasions, the charcoal canisters and accumulator were placed in essentially the same locations, at the same time, for duplicate sampling. The results of this side-by-side study show generally good correlation between the two methods.

A set of 10-minute high-volume particulate air samples was taken to determine both short-lived radon daughter concentrations and long-lived gross alpha activity. The highest levels were detected in November 1980, near and inside the Butler-type building which has since been removed. These two samples approximately equal NRC's 10 CFR Part 20, Appendix B, alternate concentration limit of one-thirtieth WL for unrestricted areas.

In addition to the routine 10-minute samples, five 20-minute high-volume air samples were taken and counted immediately on the IG gamma spectroscopy system to detect the presence of Rn-219 daughters. All samples were taken near surface contamination. In addition to Rn-222 daughter gamma activities, Rn-219 daughters were detected by measuring the low-abundance gamma rays of Pb-211. Concentrations of Rn-219 daughters ranged from 6×10^{-11} to 9×10^{-10} µCi/cc.

Vegetation Analysis

Vegetation samples included weed samples from onsite locations and farm crop samples (winter wheat) near the northwest boundary of the landfill. This location was chosen because runoff from the fill onto the farm field was possible. No elevated activities were found in these samples.

Water Analyses

A total of 37 water samples was taken: 4 in the fall of 1980, and the remainder in the spring and summer of 1981. One sample was equal to the U.S. Environmental Protection Agency (EPA) gross alpha activity standard for drinking water of 15 pCi/liter and that was a sample of standing water near the Butler-type building. Several samples, including all the leachate treatment plant samples, exceeded the EPA drinking water screening level for gross beta which would require isotopic analyses. Subsequent isotopic analyses indicated that the beta activity could be attributed to K-40. None of the offsite samples exceeded either EPA standard or screening level.

In 1981, MDNR collected 41 water samples which RMC analyzed for radioactivity (Table 3.1). Of these samples, 5 were background, 10 were onsite surface water, 10 were shallow groundwater standing in boreholes, and 16 were landfill leachate. From these data, background activity is estimated as 1.2 pCi/liter gross alpha and 27 pCi/liter gross beta. Results in Table 3.1 show the gross alpha in two water samples exceeded or equaled 15 pCi/l; the gross beta in ten water samples exceeded 50 pCi/l. Most of the gross beta activity comes from naturally occurring K-40 as determined from subsequent isotopic analysis.

In addition, groundwater samples in perimeter monitoring wells at the West Lake Landfill were taken by UMC personnel and ORAU in 1983, 1984, and 1986. The well locations are shown in Figure 2.5 and the results are presented in

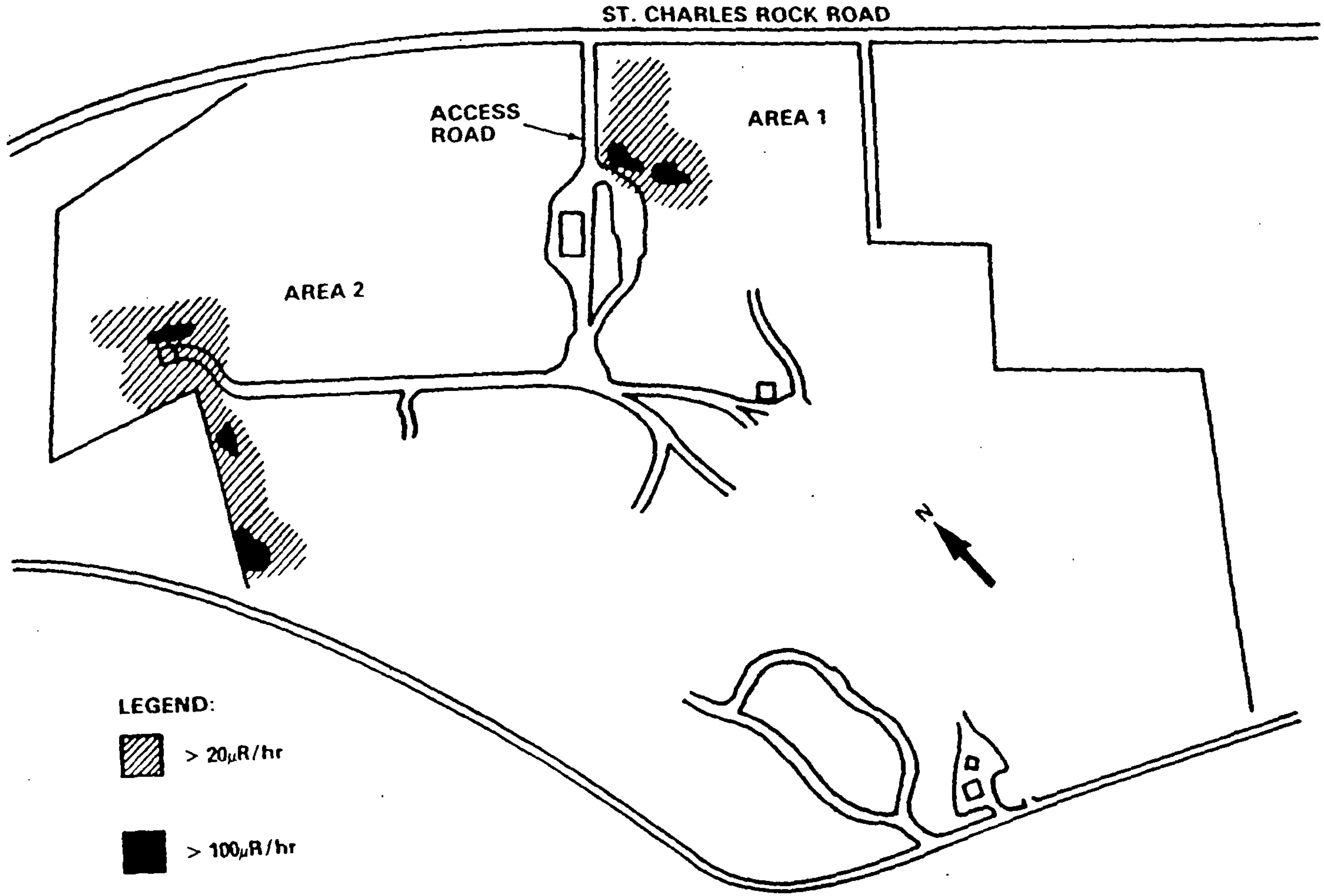
Tables 3.2 and 3.3. Results in Table 3.2 show the gross alpha in two water samples slightly exceeded 15 pCi/l; the gross beta were all below 50 pCi/l in all water samples. Table 3.3 shows analyses were below 15 pCi/l for gross alpha and 50 pCi/l for gross beta for all the wells.

3.3 Estimation of Radioactivity Inventory

In examining the RMC report for bore hole samples (Table 3.3), it is noted that the naturally occurring U-238 to Th-230 to Ra-226 equilibrium has been disturbed. The RMC report (NRC, NUREG/CR-2722) indicates that the ratio of Ra-226 to U-238 is on the order of 2:1 to 10:1. This observation is consistent with the history of the radionuclide deposits in the West Lake Landfill, i.e., that they came from the processing of uranium ores to extract the uranium content and that the radioactive material at West Lake came from the former Cotter Corporation facility on Latty Avenue (presently occupied by Futura Coatings Company) in Hazelwood, Missouri. This location contains contamination from ore processing residues from which uranium had been previously separated, leaving the daughters behind at relatively higher concentrations. Additionally, it is noted in the RMC report that the ratio of Th-230 to Ra-226 is on the order of 5:1 to 50:1. This indicates that radium has also been removed. Other data are available in the Latty Avenue site study (Cole, 1981). Table 3.4 presents the radionuclide concentrations in Latty Avenue composite samples.

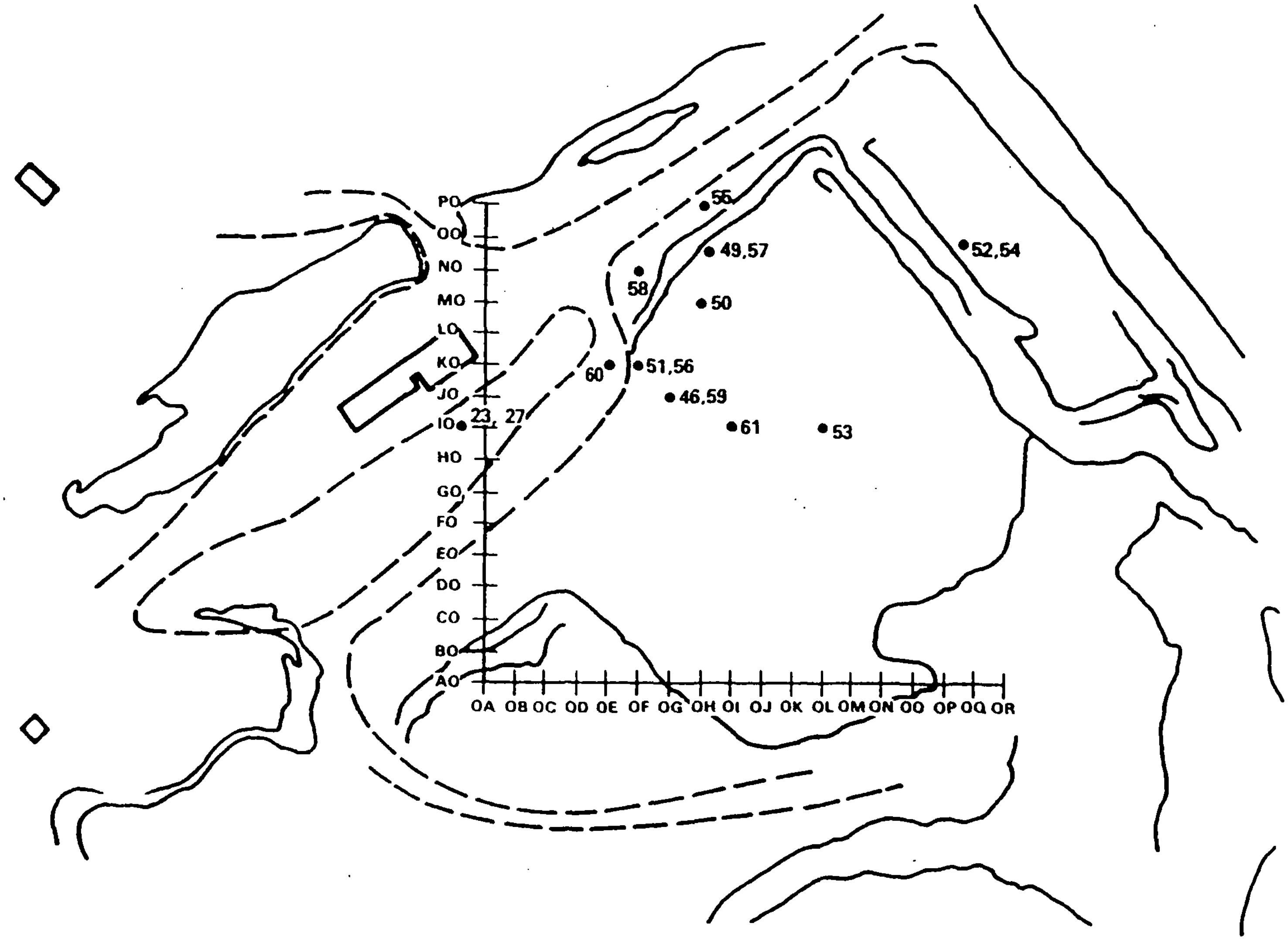
Using the RMC data and averaging the auger hole measurements over the two volumes of radioactive material found in Areas 1 and 2, a mean concentration of 90 pCi/g was calculated for Ra-226. Also, the ratios of Th-230 to Ra-226 were established since the level of Th-230 will determine the increase of Ra-226 with time. Although the ratio of Th-230 to Ra-226 ranged from 5:1 to 150:1, most of the data were in the 30:1 to 50:1 range. To ensure conservatism in estimating the long-term effects of Ra-226, a ratio of 100:1 was used for all further calculations.

Using the Th-230:Ra-226 ratio of 100:1, the Th-230 activity is 9000 pCi per gram. If the U-238 concentration (as well as U-234 which would be similarly separated from the ore) is a factor of 5 less than Ra-226, this implies about 18 pCi U-238 per gram. The total mass of radioactive material (having Ra-226 concentrations of 5 pCi/g or more) in the landfill was estimated by visually integrating the volume of radioactive material from graphs and multiplying by an average soil density, resulting in 1.5×10^{11} grams (150,000 metric tons) of contaminated soil. These numbers indicate that there are about 14 Ci of Ra-226 contained with its decay products in the radioactive material in the landfill. The material also contains about 3 Ci each of U-238 and U-234, and about 1400 Ci of Th-230. These estimates indicate the order of magnitude of the quantities to be dealt with, although the estimate for Th-230 is regarded as conservatively large.



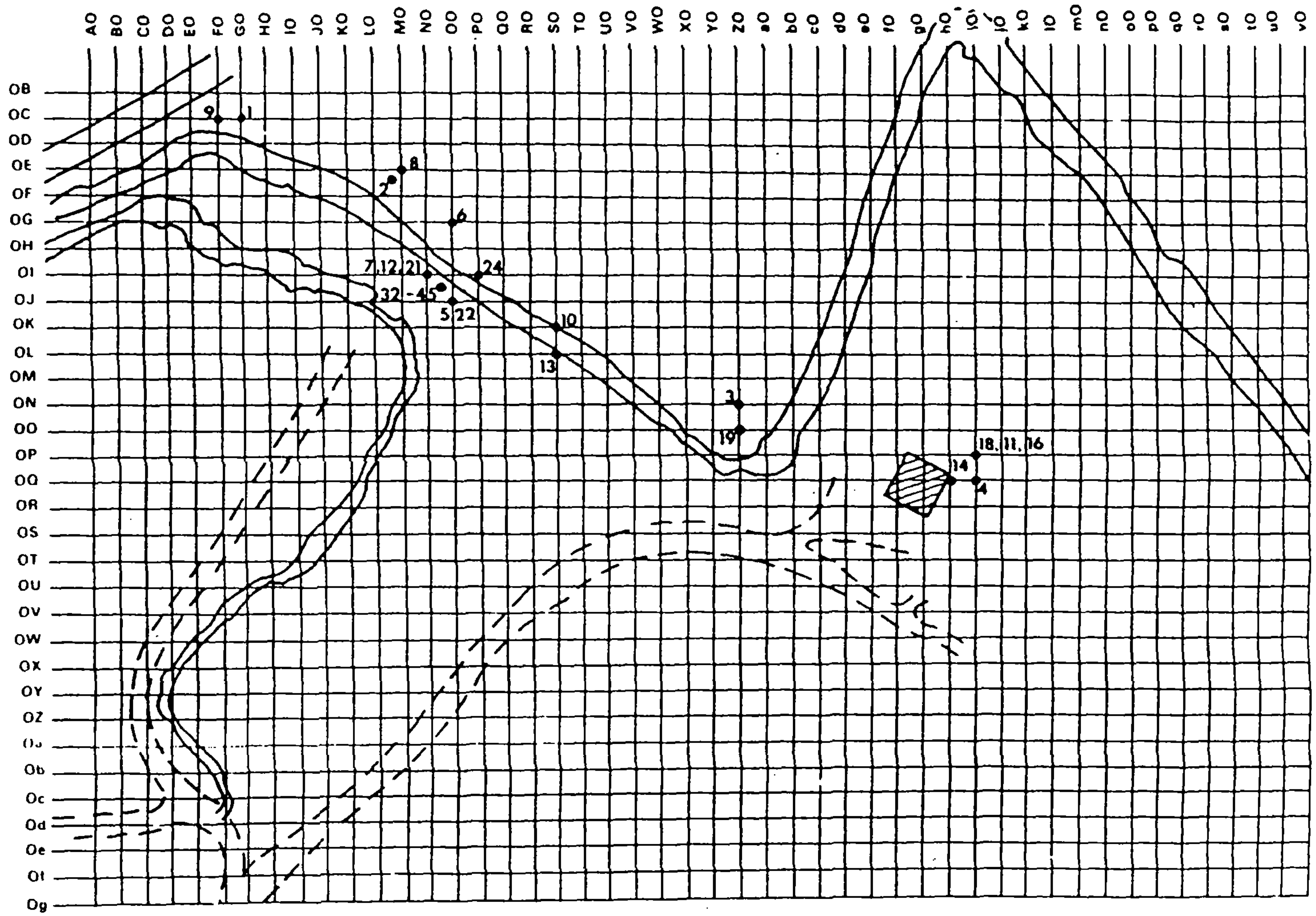
Source: NUREG/CR-2722, Figure 3, p. 27.

Figure 3.1 External gamma radiation levels (November 1980)



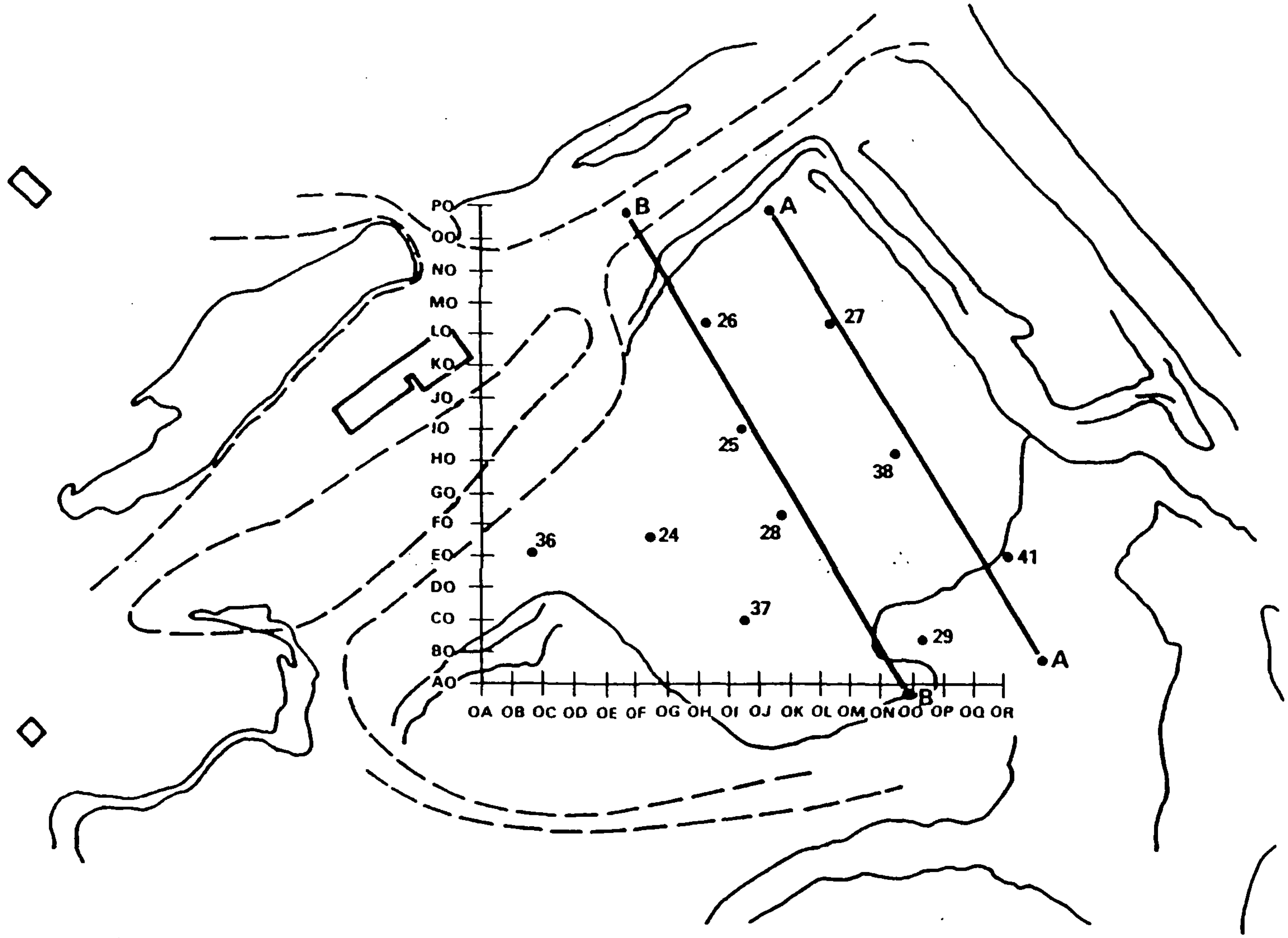
Source: NUREG/CR-2722, Figure 7, p. 31.

Figure 3.2 Location of surface soil samples, Area 1



Source: NUREG/CR-2722, Figure 8, p. 32.

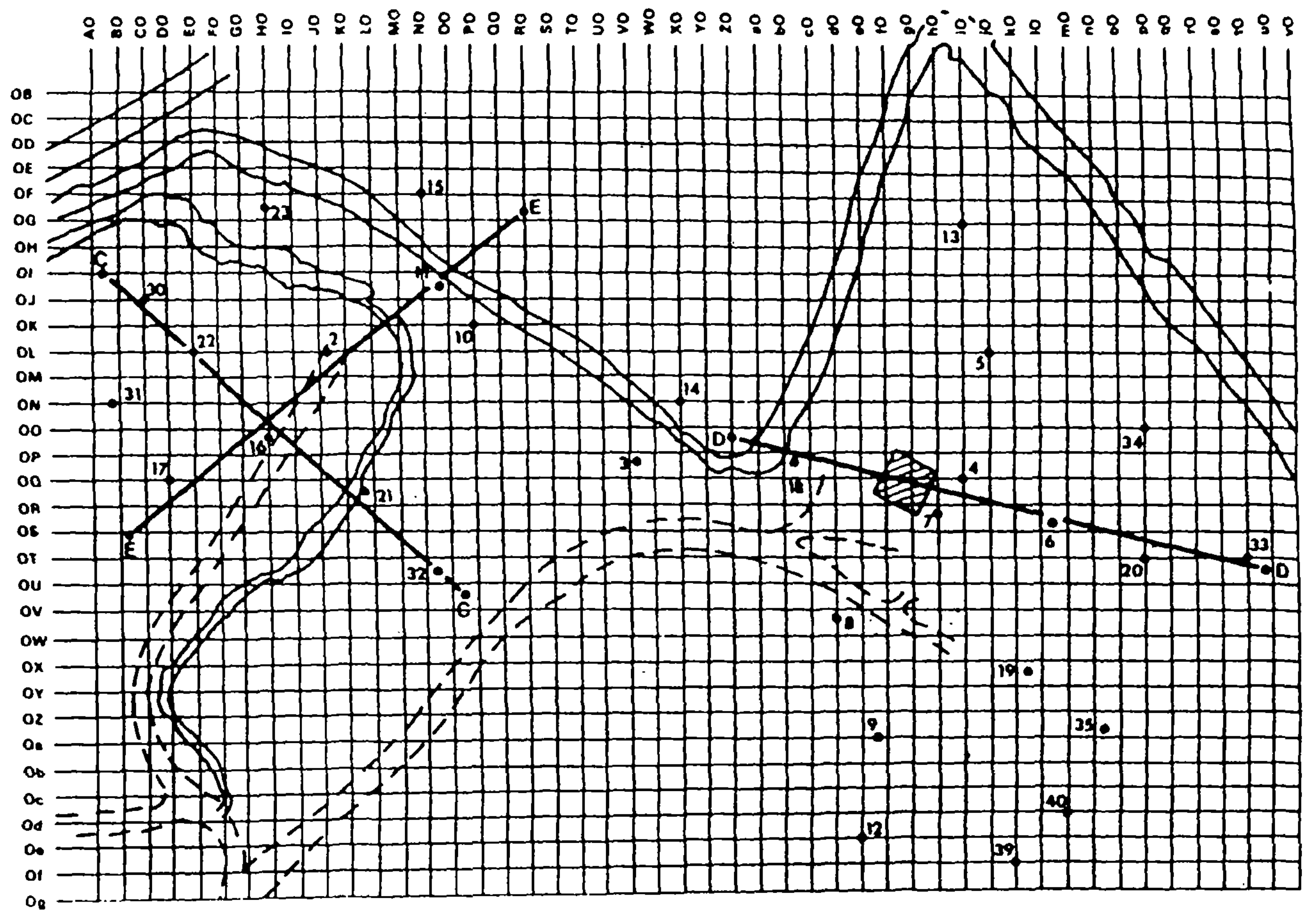
Figure 3.3 Location of surface soil samples, Area 2



Note: Line B-B indicates cross-sectional area shown in Figure 3.7.

Source: NUREG/CR-2722, Figure 9, p. 33.

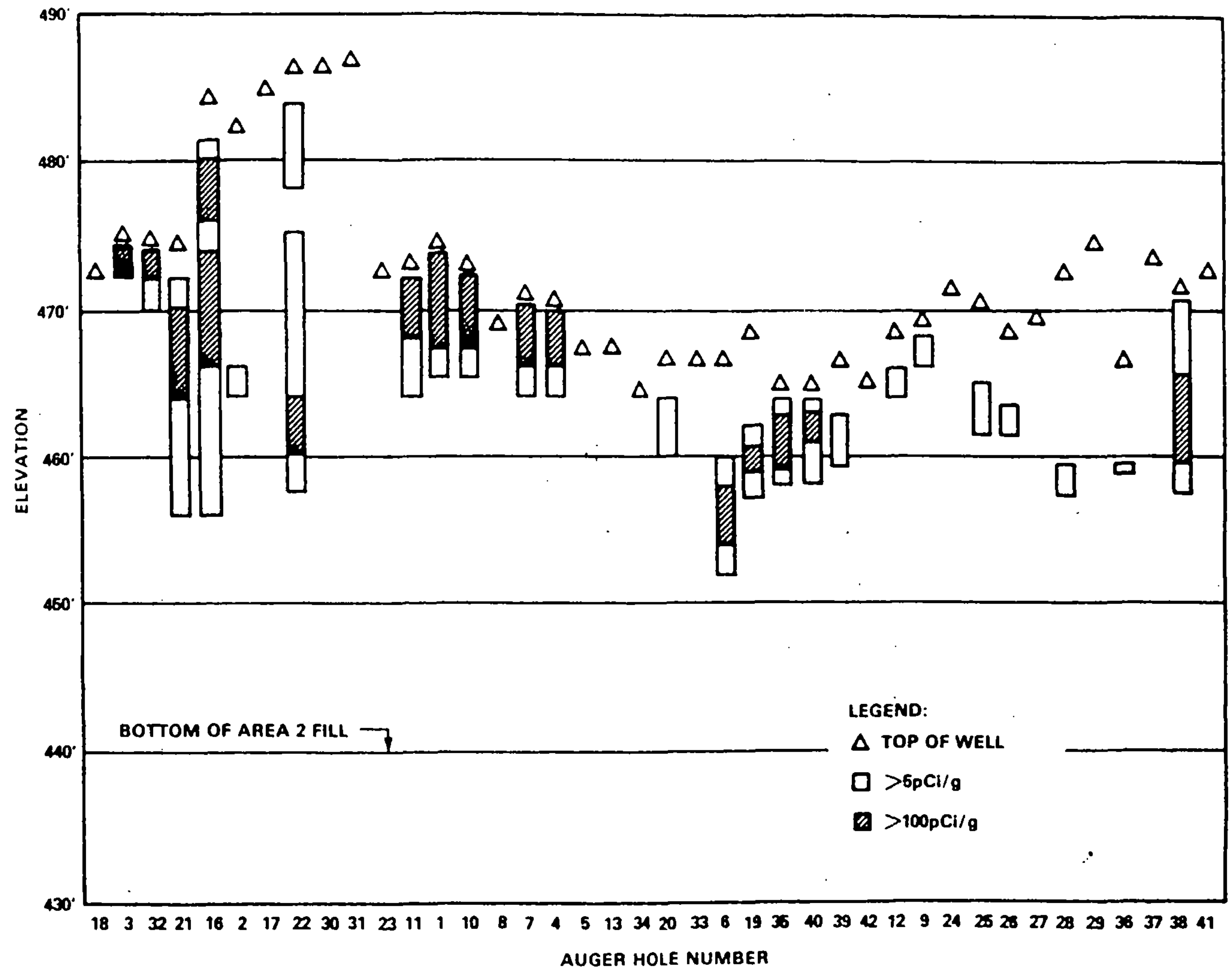
Figure 3.4 Location of auger holes, Area 1



Note: Line E-E indicates cross-sectional area shown in Figure 3.8.

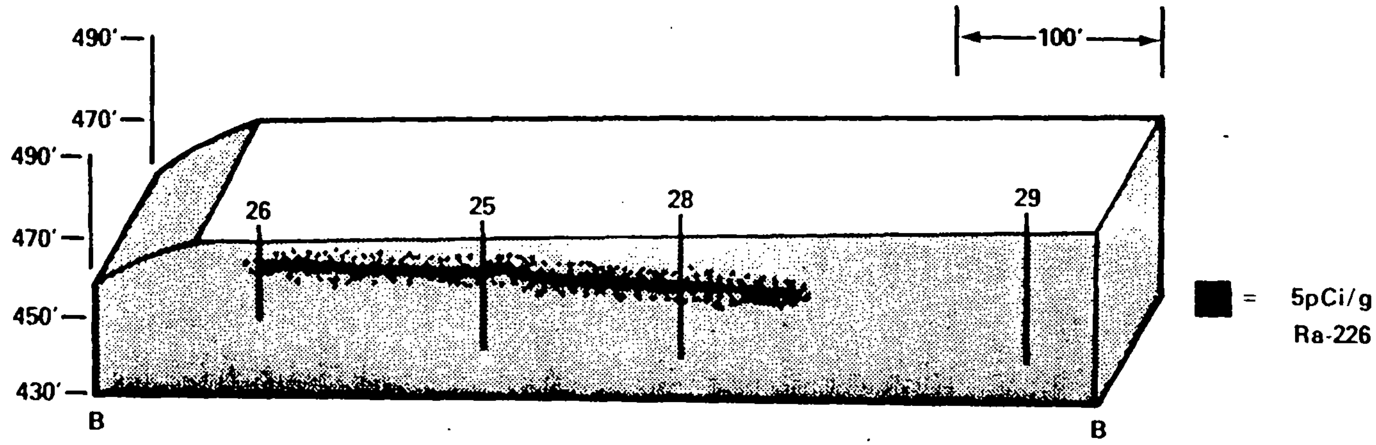
Source: NUREG/CR-2722, Figure 10, p. 34.

Figure 3.5 Location of auger holes, Area 2



Source: NUREG/CR-2722, Figure 14, p. 38.

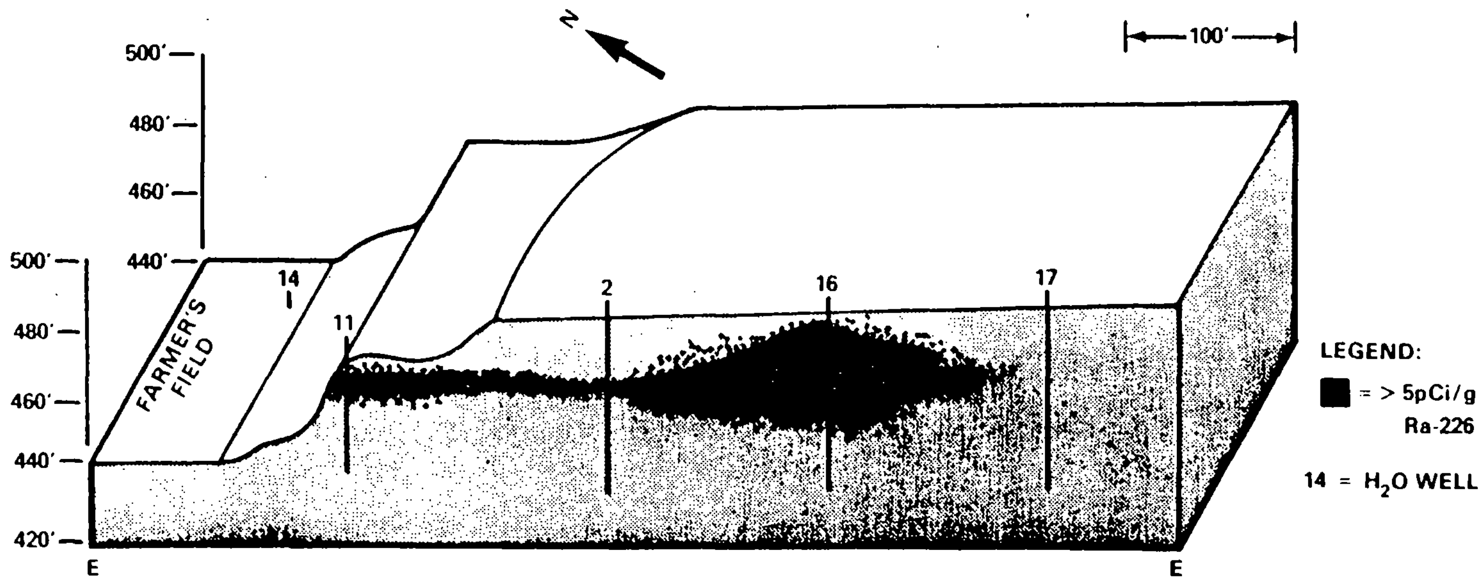
Figure 3.6 Auger hole elevations and location of contamination within each hole



Notes: (1) B-B is defined in Figure 3.4.
(2) The blackened areas indicate the estimated extent of contamination exceeding 5 pCi/g Ra-226, based on surface and auger hole measurements.

Source: NUREG/CR-2722, Figure 16, p. 39.

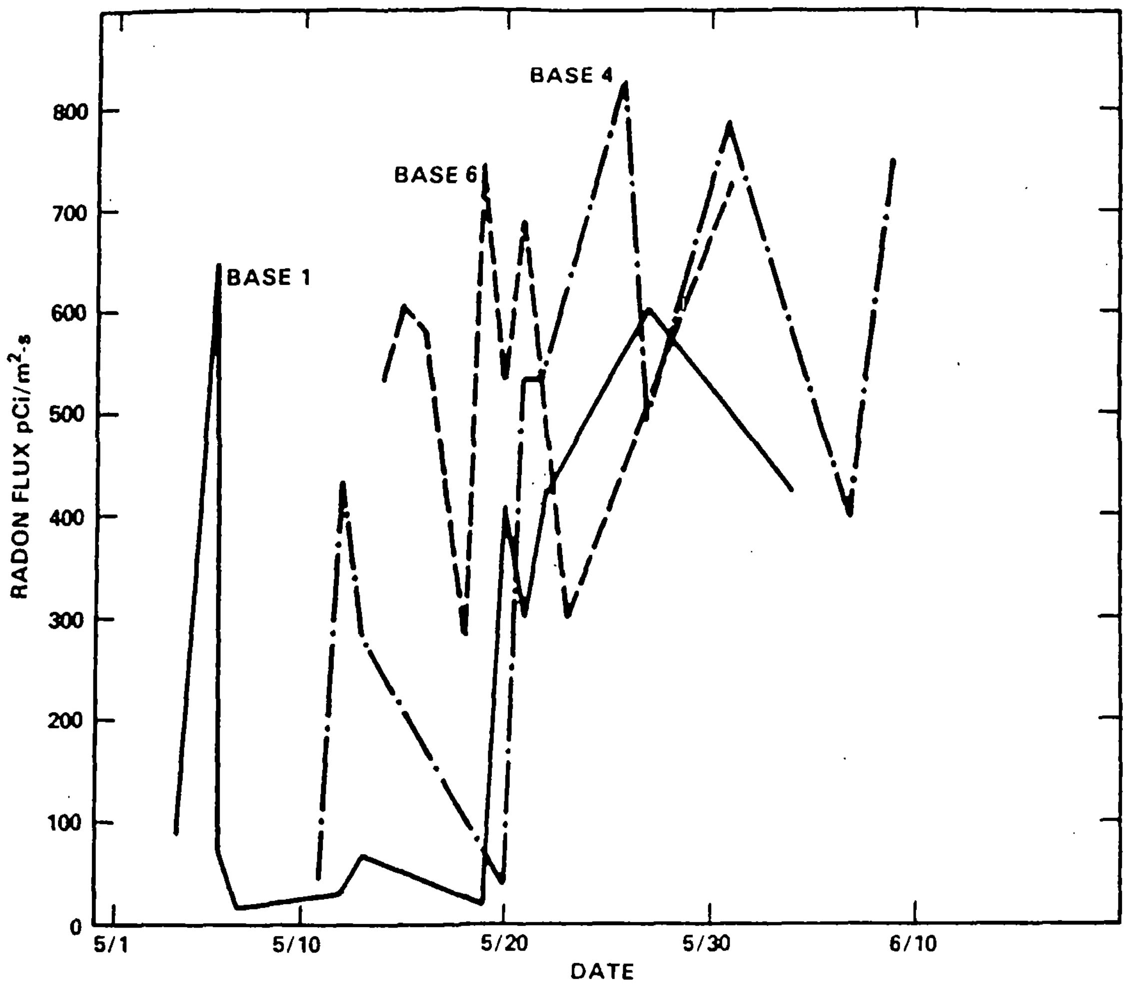
Figure 3.7 Cross-section B-B showing subsurface deposits in Area 1



Notes: (1) E-E is defined in Figure 3.5.
(2) The blackened areas indicate the estimated extent of contamination exceeding 5 pCi/g Ra-226, based on surface and auger hole measurements.

Source: NUREG/CR-2722, Figure 19, p. 42.

Figure 3.8 Cross-section E-E showing subsurface deposits in Area 2



Source: NUREG/CR-2722, Figure 20, p. 43.

Figure 3.9 Rn-222 flux measurements at three locations in Area 2 (1981)

Table 3.1 RMC radionuclide analyses of water samples from the West Lake site taken by MDNR in 1981

Sample #	Type of sample*	Gross alpha (pCi/l)	Gross beta (pCi/l)
7001	S	3.11	22.5
7002	S	8.00	23.4
7003	S	1.56	9.88
7019	S	1.91	30.0
7025	S	1.56	36.5
7028	S	45.2	87.8
7029	S	<0.64	<1.34
7030	S	0.52	35.1
7031	S	1.43	26.3
7004	B	1.04	19.7
7021	B	1.56	29.1
7027	B	1.04	32.5
7032	B	<0.05	26.3
7033	B	1.04	29.0
7009	G	4.50	22.3
7010	G	2.60	15.2
7011	G	3.12	10.6
7012	G	7.10	16.6
7017	G	0.52	33.6
7018	G	6.76	36.1
7020	G	8.84	30.1
7026	G	<2.0	38.9
2	G	15.0	41.0
3	G	2.9	7.6

See footnote at end of table.

Table 3.1 (Continued)

Sample #	Type of sample*	Gross alpha (pCi/l)	Gross beta (pCi/l)
7013	L	<3.0	1.30
7014	L	<3.0	130
7015	L	<3.0	103
7016	L	<3.0	98.9
7022	L	3.45	107
7023	L	<3.0	122
7024	L	<3.0	86.7
7034	L	<3.0	10.3
7035	L	<3.0	84.5
7036	L	<3.0	69.6
1	L	7.3	80
4	L	<3.0	26

Sample #	Type of sample*	Ra-226 (pCi/l)	K-40 (pCi/l)
7014	L	<1.6	138
7015	L	3.9	136
7016	L	<1.6	98.9
7022	L	2.4	104
7028	S	1.6	124

*S = surface sample
B = offsite, background
G = groundwater from boreholes
L = leachate

Table 3.2 Radiological quality of water in perimeter monitoring wells of West Lake Landfill (concentrations reported in pCi/l)

Well #	Ra-226	Gross alpha*	Gross beta*	Gross alpha**	Gross beta**
18	-	-	-	12.5	12.5
59	<3	3.2	9.9	-	-
60	-	-	-	20.5	20.8
61	-	-	-	2.7	13.9
62	<3	2.8	7.4	3.5	8.5
63	-	-	-	2.2	7.0
65	<3	12.4	33.1	5.7	6.3
66	<3	4.3	6.9	-	-
67	<3	5	5.3	-	-
68	<3	18.2	18.8	-	-
50***	<3	5	7.7	1.3	8.1

*Samples taken November 15, 1983.
**Samples taken March 21, 1984, by UMC personnel, analyzed by Environmental Health Lab of St. Louis County Health Department, Clayton, Missouri.
***Well #50 used as background.

Table 3.3 Radionuclide concentrations in well water samples: May 7-8, 1986

Radionuclide	Concentrations (pCi/l)						
	Well 50[a]	Well 51	Well 52	Well 53	Well 54	Well 55	Well 56
Gross alpha	2.2	2.2	1.9	11	4.4	4.8	5.7
Gross beta	7.5	4.4	7.5	16	14	14	12
Ra-226	--[b]	--	--	0.4	--	--	0.2
Ra-228	--	--	--	1.7	--	--	0.3
U-total	--	--	--	22	--	--	8.9
Th-228	--	--	--	0.5	--	--	0.3
Th-230	--	--	--	0.9	--	--	0.9
Th-232	--	--	--	0.3	--	--	0.8
Depth to water (m)	5.0	3.8	3.2	3.3	15.5	11.5	11.5

Table 3.3 (Continued)

Radionuclide	Concentrations (pCi/l)						
	Well 58	Well 59	Well 60	Well 61	Well 62	Well 65	Well 66
Gross alpha	5.8	11	14	3.3	5.6	3.5	1.8
Gross beta	15	46	19	14	10	7.4	9.9
Ra-226	0.3	0.3	2.5	--	0.8	--	--
Ra-228	2.9	0.5	1.6	--	0.6	--	--
U-total	13	25	19	--	2.3	--	--
Th-228	0.6	0.5	0.5	--	0.8	--	--
Th-230	1.5	0.2	4.4	--	1.2	--	--
Th-232	0.7	0.1	0.1	--	0.6	--	--
Depth to water (m)	14.0	Not determined	3.5	4.5	4.2	1.9	1.9

Table 3.3 (Continued)

	Concentrations (pCi/l)						
Radionuclide	Well 67	Well 68	Well 72	Well 73	Well 75	Well 76	Well 80
Gross alpha	8.4	0.9	1.4	6.5	11	3.6	0.4
Gross beta	7.1	1.9	4.6	7.7	22	6.9	3.2
Ra-226	0.7			0.3	--	--	--
Ra-228	0.3			0.9	--	--	--
U-total	7.4			3.1	16	--	2.2
Th-228	0.9			1.7	0.6	--	0.3
Th-230	9.9			6.7	12	--	0.0
Th-232	0.2			0.2	0.2	--	0.1
Depth to water (m)	1.5	4.4	10.0	8.4	7.6	13.8	5.3

Table 3.3 (Continued)

Radionuclide	Concentrations (pCi/l)						
	Well 81	Well 82	Well 83	Well 84	Well 87	Well 88	Well 89
Gross alpha	7.9	17	9.0	13	1.5	11	3.7
Gross beta	16	47	18	27	7.2	18	9.1
Ra-226	0.8	0.3	3.4	1.7	--	2.3	--
Ra-228	0.4	0.4	4.6	5.8	--	0.2	--
U-total	4.9	13	1.6	9.0	--	3.0	--
Th-228	0.9	0.4	0.2	0.6	--	1.1	--
Th-230	0.9	1.8	0.4	1.3	--	1.5	--
Th-232	0.3	0.3	1.0	1.1	--	4.0	--
Depth to water (m)	4.8	5.1	3.9	7.0	9.4	8.6	7.5

Table 3.3 (Continued)

Radionuclide	Concentrations (pCi/l)			
	Well 90	Well 92	Well 93	Well 94
Gross alpha	2.2	7.3	7.4	1.6
Gross beta	6.8	11	22	9.9
Ra-226	--	1.0	1.6	
Ra-228	--	0.8	1.4	
U-total	--	17	6.0	
Th-228	--	0.5	0.8	
Th-230	--	0.1	0.7	
Th-232	--	0.4	1.6	
Depth to water (m)	4.1	13.1	4.7	2.1

[a]Refer to Figure 2.5 for well location.

[b]Dash indicates analysis not performed.

Table 3.4 Radionuclide concentrations in Latty Avenue composite samples

	Concentrations (pCi/gm)								
Sample	U-235	U-238	Th-232*	Th-230	Th-228	Ra-226	Ra-228	Pa-231	Ac-227
Composite 1	3.6 ± 0.3**	82 ± 8	2.3 ± 0.6	8770 ± 100	2.1 ± 0.5	64 ± 1	2.3 ± 0.6	114 ± 2	205 ± 2
Composite 2	4.4 ± 0.3	62 ± 15	1.5 ± 0.5	8950 ± 370	2.0 ± 0.5	50 ± 1	1.5 ± 0.5	117 ± 8	Not Performed
Average	4.0 ± 0.2	72 ± 9	1.9 ± 0.4	8860 ± 190	2.1 ± 0.3	57 ± 1	1.9 ± 0.4	116 ± 4	205 ± 2

*Based on Ra-228 and assumption of secular equilibrium of thorium decay series.
**Errors are 2σ based only on counting statistics.

Source: Table 2 (Cole, 1981).

4 APPLICABILITY OF THE BRANCH TECHNICAL POSITION

The NRC has established a Branch Technical Position (BTP) which identifies five acceptable options for disposal or onsite storage of wastes containing low levels of uranium and thorium (46 FR 52061, October 23, 1981). Options 1-4 provide methods under 10 CFR 20.302, for onsite disposal of slightly contaminated materials, e.g., soil, if the concentrations of radioactivity are small enough and other circumstances are satisfactory. The fifth option consists of onsite storage pending availability of an appropriate disposal method. Table 4.1 shows the radionuclide concentrations specified for the disposal options.

The material present in the West Lake Landfill is a form of natural uranium with daughters, although the daughters are not now in equilibrium. As mentioned above, the average concentration of Ra-226 in the West Lake Landfill wastes is about 90 pCi per gram, which (considered by itself) falls into Option 4 of the BTP since Option 4 criteria are controlled by the Ra-226 content in the wastes (i.e., 200 pCi of U-238 plus U-234 per gram would be accompanied by 100 pCi of Ra-226 per gram). However, because of the large ratio of Th-230 radioactivity to that of Ra-226, the radioactive decay of the Th-230 will increase the concentration of its decay product Ra-226 until these two radionuclides are again in equilibrium. Assuming the ratio of activities of 100:1 used above, the Ra-226 activity will increase by a factor of five over the next 100 years, by a factor of nine 200 years from now, and by a factor of thirty-five 1000 years from now. All radionuclides in the decay chain after Ra-226 (and thus the Rn-222 gas flux) will also be increased by similar multiples. Therefore, the long-term Ra-226 concentration will exceed the Option 4 criteria.

Table 4.1 Summary of maximum soil concentrations permitted *under disposal options*

Source: 46 Federal Register 52061

Kind of material	Disposal options			
	1[a]	2[b]	3[c]	4[d]
Natural thorium (Th-232 + Th-228) with daughters present and in equilibrium. (pCi/g)	10	50	-	500
Natural uranium (U-238 + U-234) with daughters present and in equilibrium. (pCi/g)	10	-	40	200

[a]Based on EPA uranium mill tailings cleanup standards.

[b]Concentrations based on limiting individual intruder doses to 170 mrem per year.

[c]Concentration based on limiting equivalent exposure to 0.02 WL or less.

[d]Concentrations based on limiting individual intruder doses to 500 mrem per year and, in cases of natural uranium, limiting exposure to Rn-222 and its decay product airborne alpha emitters to 0.02 WL or less.

5 REMEDIAL ACTION ALTERNATIVE CONSIDERATIONS

The radioactive material as it presently exists does not pose an immediate health hazard for individuals living or working in the area of the landfill. However, there is a long-term potential for the radioactive material to pose a health problem. Therefore, this section discusses six (A-F) possible courses of action, of which all but A and D are considered temporary. Option A, in which no remedial action is proposed, is unacceptable because the concentrations of radionuclides in the landfill will become too high; Option A is described for comparison purposes only. Costs are based on the Dodge Guide to Public Works and Heavy Construction, 1984.

5.1 Option A: No Remedial Action

Under Option A, no remedial work would be done on the West Lake site. The landfill and the radioactive soil would be left in their present condition. The contaminated areas would be available for demolition fill emplacement and final closure. It is not certain how much additional fill would be emplaced. Filling would be followed by normal landfill closure operations.

Normal closure procedures consist of applying at least 0.61 m (2 ft) of compacted final cover. A 0.3-m (1 ft) layer of topsoil would be placed over the cover and upgraded to support vegetation. Establishment of a vegetative cover would require seeding, liming, and fertilization. Surface seeps of leachate would be eliminated. Maintenance of the monitoring wells would be required to allow continued sampling by MDNR, should MDNR require such action. The public would be discouraged from entering the site. After closure, a detailed description of the site would be filed with the County Recorder of Deeds. This description would include: a legal description of the site, types and location of wastes present, depth of fill, and description of any environmental control or monitoring systems requiring future maintenance (MDNR, January 1983). MDNR regulations also specifically prohibit excavation or disruption of the closed landfill without written approval of MDNR; no time frame is stated with this regulation (MDNR, 1975).

There would be no further cost under this option since no remedial actions would be taken; i.e., costs are normal landfill costs.

5.2 Option B: Stabilization on Site With Restricted Land Use

Two areas in the landfill contain radioactive material. Therefore, the work required for this option is described separately for each area. Nevertheless, restrictions would be imposed on the use of land within each area. This would discourage future activities on these areas which might expose individuals to radioactivity. No additional landfill would be permitted to be deposited on either area.

Area 1

It is believed that a total of 2 to 3 m (7 to 10 ft) of soil has been added to most of Area 1 since the 1981 land survey by RMC. This cover has altered the radiation environment of the site. Measurements by Oak Ridge Associated Universities (ORAU) personnel in March 1984 (Berger) showed that only a very small area exceeded the exposure rate of 20 μR/hr at 1 m. By extending the cover 20 m (66 ft) outward in all directions from the area showing an unacceptable surface exposure rate, the shallow wastes likely to give high rates of radon emanation will also be covered. The amount of radioactive debris in Area 1 is relatively minor compared with that present in Area 2. Therefore, a soil cover of 1.5 m (5 ft) is considered adequate to reduce surface exposure rates and radon emanation. After the soil cover is in place, a layer of topsoil 0.3 m (1 ft) thick would be emplaced, seeded, and mulched.

Area 2

Vegetation over Area 2 as well as on the slope of the berm would be cleared and placed in the demolition portion of the landfill or disposed of as is convenient. Brush should not be left in place and covered since this may reduce the integrity of the soil cap. Grass should be mowed, and may be left in place.

The berm on the northwest portion of the landfill which contains an estimated 7,500 m^3 (9,800 yd^3) of contaminated soil would be excavated and redeposited in layers in a secure portion of the landfill. The actual amount can be determined by survey during implementation of the work.

All equipment and materials now stored over Area 2 would be removed to other portions of the site or disposed of as is convenient to the owners. Gravel piles found on Area 2 should be removed to other portions of the site after having been surveyed to ensure that contaminants have not been mixed with the gravel. However, the lower 10 to 15 cm (4 to 6 in.) of rock should be left in place and covered with the soil cap, since this gravel may have become mixed with contaminated soil.

Such stabilization would place the contaminated soil well below the surface and would prevent radioactive materials from eroding as can now occur along sections of the berm. Stabilization would require emplacement of a soil cover of 48,000 m^3 (63,000 yd^3) to give a final slope of 3:1 with 1.5 m (5 ft) of soil at the top of the berm. At least 1.5 m (5 ft) of soil cover would be used, as this much soil will be required to reduce radon gas exhalation. The final slope of 3:1 on the berm would be shallow enough to prevent failure and, after the cover is emplaced, it should be further covered with at least 0.3 m (1 ft) of topsoil and seeded with native grasses to prevent erosion. The slope would be directed radially outward from the center of the cap. An interceptor ditch would be provided around the cap to channel runoff and prevent gullies from being cut into the stabilized cover. The cover soil presently used in the landfilling operations may be used to stabilize the berm. This soil is a clay silt (loess) excavated near the West Lake Landfill site.

The portion of Area 2 to be covered by the soil cap includes that portion of the landfill identified in the RMC survey as having surface exposure rates greater than 20 μR/hr at 1 m (3.3 ft) above ground level, along with those areas in which auger holes revealed radium-bearing soil within 1 m of the surface. The shallow contaminants may be sufficiently shielded to produce low surface exposure rates; however, these shallow deposits will still produce radon emanations greater than the desired level of 20 pCi/m^2s. Therefore, the soil cover must be extended over these areas of shallow contamination.

The cover soil used should be capable of compaction to a permeability of less than 10^{-7} cm/s in order to keep radon release and soil leaching as low as possible. This value is based on common practices used for sealing of hazardous waste landfills. Because accurately measuring permeability of this magnitude is difficult, the value of 10^{-7} cm/s should be used only as a target criterion which should, if possible, be bettered. If laboratory testing of the cover soil presently used at the West Lake Landfill indicates that this permeability can be achieved, this soil would be acceptable for use as the soil cap. Otherwise, clay soil would have to be imported from off the site to be used in constructing the soil cap.

The overall estimated cost for the required work under Option B is approximately $360,000 (Table 5.1) and would require about 2 months to complete. Costs of this option may be higher if the total quantity of contaminated material to be moved is higher than the estimated quantity.

5.3 Option C: Extending the Landfill Off Site

Soil eroding on the northwest berm of Area 2 is carrying contaminated soil off the landfill property onto an adjacent cultivated field. A contributing factor to the erosion is the steepness of the berm. It would, therefore, be desirable to lessen the slope's steepness by extending the berm onto the adjacent field. This option would require the acquisition of approximately 2 ha (5 acres) of land not owned by the landfill company.

In this option, Area 1 would be treated the same as in Option B. The contaminated portion of the northwestern berm of Area 2 would not be disturbed. Instead the existing berm would be extended 13 to 16 m (42 to 52 ft) onto the adjacent field. This would require an additional solid volume of approximately 20,200 m^3 (26,400 yd^3) to give a final slope of 3:1 with 1.5 m (5 ft) of soil on top of the berm. As in Option B, this cover should receive an additional 0.3 m (1 ft) of topsoil and be seeded with native grasses to prevent erosion.

This option will require the relocation of three transmission poles. All other necessary work for Option C is as described for Option B.

The overall estimated cost for required work under Option C is approximately $470,000 (Table 5.2) and would require about 2 months to complete. The extent of work required under this option is well defined.

5.4 Option D: Removing Radioactive Soil and Relocating It

This option would involve excavating and removing all contaminated soil and debris from the West Lake Landfill and relocating it to an authorized disposal facility.

Vegetation over Areas 1 and 2 would be cleared and placed in the demolition portion of the West Lake Landfill.

All equipment stored on the two contaminated areas would be removed to another portion of the site. Gravel piles in Area 2 should be removed. The lower 10 to 15 cm (4 to 6 in.) of rock should be left in place to be disposed of with other contaminated materials, since this gravel may have become mixed with contaminated soil at the surface.

The areas known to contain radioactive contamination at levels above the action criteria (20 μR/hr at 1 m) would be excavated initially. Next, the excavated area would be surveyed to determine the extent of contamination remaining. Excavation would continue until unacceptable levels of contamination have been removed. Immediately after excavation, the soil would be placed in 208-liter (55 gal) approved drums (or other approved containers) for transport. Containment in the drums will prevent the spread of dust and loose soil during transport.

Some of the nonradiological hazardous material known to be present in the landfill could present a serious danger to workers should they excavate into this material. Proper precautions should, therefore, be taken as the work is being performed.

Estimated costs under Option D would be $2,500,000 (Table 5.3). Transporting the contaminated soil to another site and emplacing the material there would significantly add to the cost. This option could be completed in about

3 months, providing that a suitable disposal facility were available to receive the contaminated waste.

5.5 Option E: Excavation and Temporary Onsite Storage in a Trench

Under this option, as much radioactive soil would be excavated as in Option D and would be placed in a specially prepared trench on the West Lake site but would not be placed in drums. This trench would become a temporary repository for the radioactive soil. The trench would be surrounded by an impervious clay liner to minimize leachate production and transport into the groundwater system. The cap should give acceptable rates of surface exposure and acceptable rates of radon gas release.

As under Option D, surface vegetation, machinery, and piles of crushed rock would be removed from the surface of areas to be excavated. Design of the trench is based upon the "secure landfill concept" (Shuster and Wagner, 1980) with three primary functions: eliminate direct gamma-ray exposure at the ground surface, reduce radon emanation, and prevent leaching of radionuclides to the groundwater system.

The excavated area would be cut to a maximum elevation of 140 m (460 ft) msl over the area to be covered by the trench. The base of the trench would cover an area 120 x 120 m (394 x 394 ft) and would have a negligible slope. Low spots would be filled with borrow soil* compacted to at least 90% of its standard Proctor density (SPD). Once the base for the trench has been leveled to a final elevation of about 140 m (460 ft) msl, a blanket of borrow soil at least 1.5 m (5 ft) thick compacted to at least 90% SPD would be emplaced. Specification of compaction of this underlayer is based on the requirement of avoiding subsidence which could cause the clay liner to crack and fail. A clay liner would be placed above the underlayer. The liner would be 0.5 m (1.6 ft) thick and would have a permeability less than 10^{-8} cm/s (4×10^{-9} in./s). An impermeable plastic liner could also be used.

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*Borrow soil refers to a clayey-silt loess (Soil Conservation Service type CL) excavated southeast of the site for use as daily cover in the landfilling operation.

Sides of the trench would be built at a 3:1 slope up to the level of the surrounding undisturbed landfill surface, about 143 m (470 ft) msl. The walls would consist of an underlayer and liner as described for the base. A layer of crusher-run limestone 0.5 m (1.6 ft) thick would be placed on top of the liner to allow leachate buildup in the trench to be monitored and to facilitate pumping should leachate buildup become a problem.

After the base and walls of the trench have been built, the previously excavated debris would be placed in the trench. Then the remaining radioactive debris would be excavated and placed in the trench. As excavation proceeds, it will become apparent how much volume the trench must have to contain all the contaminated soil. At this point, the walls of the trench would be raised to an appropriate level. Excavation and filling can then proceed until the work is complete. The final thickness of debris is expected to be from 4 to 6 m (13 to 20 ft).

A cover, as described below, would be placed over the debris. A 1 m (3 ft) layer of borrow soil compacted to 90% SPD will be placed over the debris. A clay liner 0.5 m (1.6 ft) thick of permeability less than 10^{-8} cm/s (4 x 10^{-9} in./s) would be placed over the borrow soil blanket. A 0.5-m (1.6-ft) layer of crusher-run limestone would be placed over the clay layer to prevent infiltration water from building up over the liner. A cover soil layer of average thickness about 2 m (7 ft) would be placed over the rock layer.

The cover soil would be compacted and built with a surface slope of from 2% to 4% to minimize erosion. Three-tenths of a meter (1 ft) of top soil would be placed over the cover layer and would be seeded and mulched to establish a vegetative cover.

Once the trench has been prepared to accept the soil, workers may begin to excavate contaminated soil. As under Option C, an initial excavation would remove the area of known contamination, and a cleanup phase would remove all soil containing radionuclide concentrations above an action level of 15 pCi/g Ra-226. As soon as the soil has been excavated, it would be hauled to the trench and emplaced. The contaminated soil should be sufficiently compacted to prevent settling, to maintain the integrity of the soil cap. As fill is being emplaced, the pipe for a monitoring well would be extended upward from the base of the gravel underdrain. This well should be designed in a manner that would allow future installation of a pump for drawing off leachate should this become necessary.

Costs for Option E would be approximately $2,150,000 (Table 5.4). The estimated costs vary somewhat, since the exact limits of excavation cannot be defined until work begins. This work would require approximately 4 months to complete.

5.6 Option F: Construction of a Slurry Wall to Prevent Offsite Leachate Migration

Under Option F, radioactive soil would be left in place at the West Lake site. The wastes would be stabilized by means of a soil cover (as under Option B) and a downgradient slurry wall would be built around the contaminated soil. The slurry wall would be intended to keep leachate from migrating off site. This remedial action would be somewhat more effective than Option B in reducing the potential for groundwater contamination. However, costs incurred would be substantially higher than those for Option B or C. Benefits would be nearly identical to those derived by the soil cover and berm stabilization alone; the sole advantage of Option F over Option B or C would be greater protection to groundwater in the Missouri River alluvium.

Vegetation, machinery, and piles of crushed rock would have to be removed as described for Option B. A slurry wall would be constructed by excavating a trench [approximately 1 m (3.3 ft) wide] to the depth of bedrock. This trench would be bored out in the presence of a mud weighted with bentonite (clay) to keep the walls from collapsing and to keep groundwater from intruding into the trench. The trench would be excavated in sections 6 to 8 m (20 to 26 ft) long. Once a section of trench has been excavated, concrete would be poured by tremie into the trench to displace the slurry. The final slurry walls would each consist of a concrete slab about 1 m (3.3 ft) thick extending to bedrock and partially encircling the bodies of radioactive soil in both Areas 1 and 2. A total of approximately 1300 linear meters (4,300 ft) of wall would be constructed to depths varying from 5 to 15 m (16 to 50 ft).

After each of the slurry walls had been emplaced, fill would be added along the face of the berm to stabilize the slope. Finally, a soil cover would be placed over the contaminated areas. The berm would be stabilized and the soil cover would be placed as outlined for Option B.

Costs of work required for Option F would be approximately $5,600,000 (Table 5.5). The exact amount of slurry wall cannot be determined until work is begun; therefore, this cost will be highly variable. Since the walls should extend to bedrock, the depth of soil and landfill debris will govern the depth of the required wall. Slight errors in estimating the depth of alluvium could result in large errors in the cost estimate. It is estimated that it would take 6 to 8 months to complete this option.

Table 5.1 Itemized cost of remedial action, Option B

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1850/ha	$ 5,365	*
Remove Shuman Building	--	--	$ 6,200	**
Excavate contaminated soil and redeposit it at a secure site	7500 m^3	$10/$m^3$	$ 75,000	†
Emplace soil cover	48,000 m^3	$4.64/$m^3$	$222,720	†
Bury clean rubble	225 m^3	$12.50/$m^3$	$ 2,812	†
Seed and mulch cover	3.3 ha	$2165/ha	$ 7,145	*
Subtotal			$319,242	
Contingency @ 10%			31,924	
Engineering and legal fees @ 5%			15,962	
Estimated total cost			$360,000††	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

†Based on best estimated cost.
††Adjusted for deletion of building removal.

Table 5.2 Itemized cost of remedial action, Option C

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1850/ha	$ 5,365	*
Remove Shuman Building	--	--	$ 6,200	**
Relocate power transmission poles	3	$2060	$ 6,180	†
Stablize berm (fill)	20,200 m^3	$6.70/$m^3$	$135,340	†
Emplace soil cover	48,000 m^3	$4.64/$m^3$	$222,720	†
Bury clean rubble	225 m^3	$12.50/$m^3$	$ 2,812	†
Seed and mulch cover	3.3 ha	$2165/ha	$ 7,145	*
Subtotal			$385,762	
Contingency @ 10%			38,576	
Engineering and legal fees @ 5%			19,290	
Land acquisition	2 ha	$15,500/ha	31,000	
Estimated total cost			$470,000	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

†Based on best estimated cost.

Table 5.3 Itemized cost of remedial action, Option D

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1850/ha	$ 5,365	*
Remove Shuman Building	--	--	$ 6,200	**
Bury clean rubble	230 m^3	$12.5/$m^3$	$ 2,875	†
Excavate contaminated soil	70,000 m^3	$5.25/$m^3$	$ 367,500	†,††
Site decontamination	27,600 m^3	$1.4/$m^2$	$ 38,640	***
Packing waste for transportation	70,000 m^3	$25/$m^3$	$1,750,000	†
Subtotal			$2,170,580	
Contingency @ 10%			217,058	
Engineering and legal fees @ 5%			108,529	
Estimated total cost			$2,500,000***	

*<u>Dodge Guide to Public Works and Heavy Construction</u>, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

***No costs have been included here for moving the waste, for emplacing it and for disposal facility users fees.

†Based upon best estimate.
††Estimated quantity of soil having Ra-226 concentrations of 15 pCi/g or more.

Table 5.4 Itemized cost of remedial action, Option E

Item	Quantity	Unit price	Cost	Reference
Prepare secure trench	80,000 m^3	$9/$m^3$	$ 720,000	*
Clearing and grubbing	2.9 ha	$1,850/ha	$ 5,365	*
Remove Shuman building			$ 6,200	**
Bury clean rubble	230 m^3	$12.5/$m^3$	$ 2,875	*
Excavate contaminated soil	70,000 m^3	$5.25/$m^3$	$ 367,500	*
Site decontamination	27,600 m^3	$1.40/$m^3$	$ 38,640	†
Emplace contaminated soil	70,000 m^3	$10.3/$m^3$	$ 722,200	*
Monitoring well	---	---	$ 6,000	*
Seed and mulch cover	0.08 ha	$2,165/ha	$ 200	†
Subtotal			$1,868,980	
Contingency @ 10%			186,900	
Engineering and legal fees @ 5%			93,450	
Estimated total cost			$2,150,000	

* Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

† Based on best estimate.

Table 5.5 Itemized cost of remedial action, Option F

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1,850/ha	$ 5,365	*
Remove Shuman building			$ 6,200	**
Relocate power transmission poles	7 poles	$2,060/@	$ 14,420	†
Construct slurry wall	11,000 m^2	$402/$m^2$	$4,422,000	*
Stabilize berm	20,200 m^3	$6.70/$m^3$	$ 135,340	†
Emplace soil cap	48,000 m^3	$4.64/$m^3$	$ 222,720	†
Bury clean rubble	225 m^3	$12.5/$m^3$	$ 2,812	†
Seed and mulch cover	3.3 ha	$2,165/ha	$ 7,145	*
Subtotal			$4,816,002	
Contingency @ 10%			481,600	
Engineering and legal fees @ 5%			240,800	
Land acquisition	2 ha	$15,500/ha	31,000	
Estimated total cost			$5,600,000	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

†Based on best estimate.

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25pgs.

December 12, 1989

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Mr. Joseph G. Homsy
Katten, Muchin and Zavis
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Suite 1600
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Dear Mr. Homsy:

RE: West Lake Landfill CERCLA

This letter was drafted at the direction of Mr. Joseph G. Homsy regarding the proposed listing of the West Lake Landfill in Bridgeton, Missouri to the National Priorities List (NPL). This letter documents the results of Foth & Van Dyke's investigation regarding the hazardous ranking system (HRS) scoring package and background (support) information for the West Lake Landfill. In addition, an evaluation was made based upon currently available information for the site to ascertain if pollutant or contaminant releases may present imminent and substantial danger to public health and welfare.

HRS Evaluation

The West Lake Landfill site was scored for two routes only: groundwater and surface water. The elements of the groundwater route score were observed release, waste characteristics (toxicity/persistence and hazardous waste quantity) and targets (groundwater use and distance to nearest well/population served). I believe that documentation of an observed release, toxicity/persistence and hazardous waste quantity exit. The only possible areas of dispute are groundwater use and distance to nearest well/population served.

The surface water route score was based upon the potential for a release. The elements of the surface water route score were route characteristics (facility slope and intervening terrain, 1-year 24-hour rainfall, distance to nearest surface water and physical state), containment, waste characteristics (toxicity/persistence and hazardous waste quantity) and targets (surface water use). I believe that documentation of the above elements with the exceptions of facility slope and intervening terrain, physical state and containment exit. However, even with the elimination of the surface route score from the total score, the revised HRS score could be lowered to only 29.49. Therefore, further evaluation of this route was not conducted.

The groundwater use score of "3" is based upon the groundwater used as drinking water with the present unavailability of municipal water from alternative unthreatened sources (40 CFR, Part 30, App A). According to a telephone record, (Reference 14 in the HRS background information) the St. Louis County Water

50 years

LAI 0294

Company does not provide service north of St. Charles Rock Road on the Missouri River floodplain.

On November 6, 1989, I reviewed maps in the engineering office of the St. Louis County Water Company. The purpose of this review was to determine the location of water mains which could provide water service north of St. Charles Rock Road on the Missouri River floodplain. A water main follows the Earth City Expressway north to St. Charles Rock Road and then heads east along St. Charles Rock Road. A water main heads northeast into the Rock Industrial Park and then southeast to Taussig Road. Another line heads northeast on Taussig/Gist Road. The water company does not have water lines west of Earth City Expressway on St. Charles Rock Road. Water lines do not exist on Ferguson Road or along Missouri Bottom Road in the Missouri River floodplain. In Attachment A there is a map indicating the locations of the water lines with plat numbers referenced in the St. Louis County Water Company maps.

On November 9, 1989, I drove throughout the area north of St. Charles Rock Road in the Missouri River floodplain and up to three miles from the West Lake Landfill site. In addition, I met with an employee of a small business on Ferguson Road and had a telephone conversation with an employee of the Old Bridge Bait Shop on St. Charles Rock Road. The purpose of this investigation was to determine the existence and use of water wells within a 3-mile radius of the West Lake Landfill site.

The wells referenced by the Missouri Department of Natural Resources (MDNR) in the HRS scoring package (Reference 12, Numbers 1 through 20) and other wells or potential well locations developed by my survey (Numbers 21 through 26) are shown on the map in Attachment B. Also included is a description of well uses. According to my field survey, wells 2 and 19 do not exist - i.e. houses/buildings are no longer present at these locations. Wells 1 and 25 are located approximately one mile from the waste boundary and well 20 is located approximately 2500 feet from the waste boundary. Employees at wells 1 and 25 stated that the water from these wells is used for cleaning purposes and is not used for drinking water. Drinking water is brought to these facilities. An employee at well 1 told me that the water was too rusty to use for drinking water.

An alternate unthreatened water supply is available for well 20. St. Louis County Water Company water lines run throughout the industrial parks to the south, west and north of well 20. In addition, this well is apparently used for irrigation/watering purposes only. Therefore, within one mile of the waste boundary, groundwater is not used for drinking water. Also, an alternate unthreatened source is presently available to the industrial parks north of St. Charles Rock Road which refutes part of Reference 14 of the HRS scoring package. According to the employee at well 1, the people at the new house on Ferguson Road (well 26) use their water for drinking water. This well is approximately 5900 feet from the waste boundary and apparently is

the nearest well to the waste boundary from which water is used as a drinking supply. Also according to a report prepared for the Nuclear Regulatory Commission (NRC) entitled "Site Characterization and Remedial Action Concepts for the West Lake Landfill" dated July, 1989, the closest drinking water is 1.4 miles from the site (Attachment C). However, the well designated as well 26 was apparently installed after the development of the data from the NRC (1989) report.

In the HRS scoring process, the MDNR has used two wells in the population served element which do not exist. Also, the MDNR state that the St. Louis County Water Company does not supply service north of St. Charles Rock Road on the Missouri River floodplain. However, a check of the maps at the St. Louis County Water Company along with the observation of fire hydrants throughout the industrial parks north of St. Charles Rock Road refute this statement. Therefore, some of the work performed by MDNR is not correct.

The result of this survey is that the groundwater use value of "3" along with the population served value by groundwater and distance to nearest well value appear to be in conflict. The value of "3" for groundwater use within three miles of the hazardous substance is for drinking water with no municipal water from alternate unthreatened sources presently available. The well used for the distance to the nearest well has an alternative unthreatened municipal water source readily available. Therefore, the use of this well for distance to nearest well and the area groundwater use are in conflict. The nearest well used for drinking water with or without an alternate unthreatened source is approximately 5900 feet north of the waste boundary. Therefore, either the groundwater use value should be reduced to "2" or the distance to the nearest well value should be reduced to "2".

The major portion of the population served by groundwater wells within a 3-mile radius (720 out of 777 people) is based upon irrigated cropland. The groundwater use value of "3" applies to drinking water, however, the groundwater use value of "2" applies to "drinking water with municipal water from alternate unthreatened sources presently available or commercial, industrial or irrigation with no other water source presently available". The fact that the population served is mainly by commercial, industrial and irrigation uses would suggest that the nature of the use made of groundwater drawn from the aquifer of concern within three miles of the hazardous substance is commercial, industrial or irrigation with no other water source presently available. The basis of the groundwater use and population served values used in the HRS score are in conflict. Therefore, either the groundwater use value should be lowered to

"2" or the population served value should be lowered to "1" (population between 1 and 100).

The scores of three scenarios for modifying the target values are provided below:

1. Change the value for groundwater use from "3" to "2"
   HRS score = 26.36

2. Change the value for distance to nearest well from "3" to "2" (matrix changes from "16" to "12")
   HRS score = 25.20

3. Change the value for population served from "2" to "1" (matrix changes from "16" to "8")
   HRS score = 20.58

The HRS score work sheets for each of the above scenarios are provided in Attachment D.

Risk Assessment

An evaluation of the impact of the site on the public health and welfare was performed by a Foth & Van Dyke toxicologist. An insufficient amount of data is available to conduct a formal risk assessment. Thus, opinion(s) presented here were based on the available information. Additional information which would be needed for a complete risk assessment is identified later.

Presently, the principal concern at the West Lake Landfill is the presence of low level radioactive waste at the site. The radioactive waste is confined to two locations at the landfill, comprising about 9 acres. Radionuclides of concern include: Uranium - 238, Uranium - 234, Thorium - 230 and Radium - 226. Exposure to these radionuclides via the groundwater, air, soil or surface water could result in formation of a cancer if the exposure was sufficient. A risk assessment would determine what constitutes a sufficient exposure. In lieu of a risk assessment, each potential exposure pathway will be discussed in a qualitative manner, with recommendations made for future laboratory/field work.

At this time groundwater does not appear to represent a significant exposure pathway. Monitoring performed for the NRC at or near the perimeter of the landfill show no to minimal radioactive contamination. An important point which must be emphasized is that exposure to groundwater through ingestion is not the only route of concern. The radionuclides present produce high energy beta particles and photons (gamma rays) which can cause tissue damage, i.e., cancer, through external exposure. Groundwater used for cleaning, agricultural and industrial uses may be cause for concern.

Recommendations

* Measure radioactivity of groundwater used at offsite locations;

* and, determine in detail, groundwater use in the area.

On-site radiation levels were measured for the NRC to determine the external gamma radiation level and the flux of radon and its metabolites. Both techniques showed unacceptable levels of radiation in the ambient air above the surface contaminated sites. These levels would pose a health risk to persons on-site for an extended period of time.

Recommendations:

* Conduct air sampling and modeling, to determine if this exposure pathway presents a health risk to persons offsite, e.g., Spanish Lake Village, Ralston-Purina employees, etc.;

* Determine if the radon flux will increase with time as the radioactive decay produces higher levels of radon;

* Assuming migration of a contaminated groundwater plume to the Missouri River, determine a future radon flux in the area west of the landfill since dwellings in this area may be subject to radon gas contamination;

* Conduct an investigation to determine if radon gas is a problem (health hazard) in buildings adjacent to the landfill.

On-site radiologic soil analysis has defined the area of contamination. In some areas the contaminated soil is covered by demolition debris and surface soil. Fugitive dust emissions, surface runoff (especially near the northwest berm) and air contamination could all serve as a source of contamination to offsite locations because of these cover materials.

Recommendations

* Determine offsite soil contamination e.g., farmers field, neighborhoods, etc.

At this time the surface water in the area is free of radioactive contamination. The Missouri River is used as a municipal water supply. In addition the water is used for recreational purposes. Onsite closure of the landfill would have to ensure that neither of these surface water uses would be jeopardized.

Recommendations

* Collect area surface water and sediment samples for radioactive contamination.

Based upon existing information, the West Lake Landfill does not appear to represent an imminent and substantial danger to public health and welfare.

If you have any questions regarding these evaluations, please contact me.

Very Truly Yours,

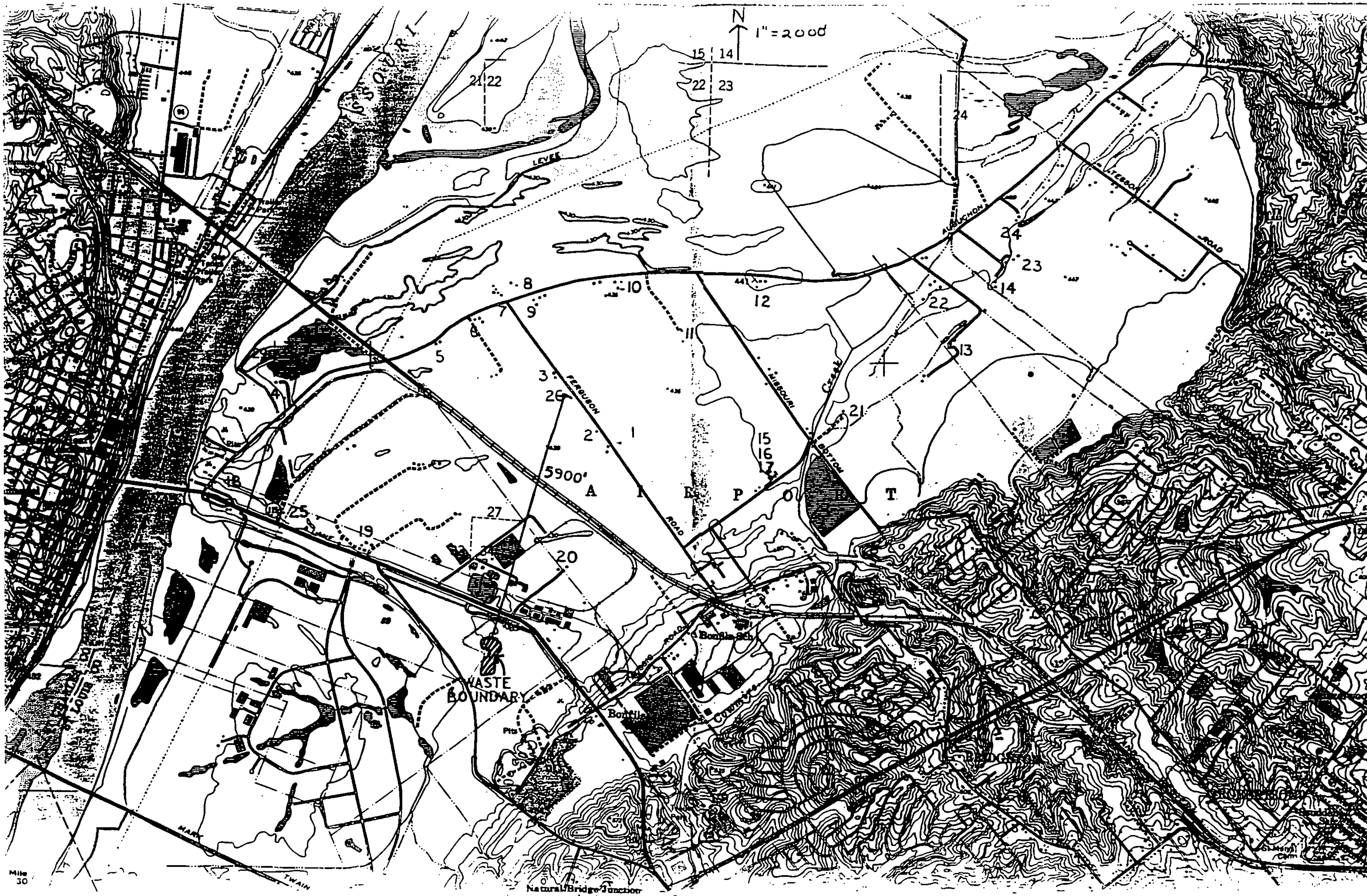
Foth & Van Dyke

Rodney T. Bloese

Rodney T. Bloese
Senior Project Hydrogeologist

RTB:klt

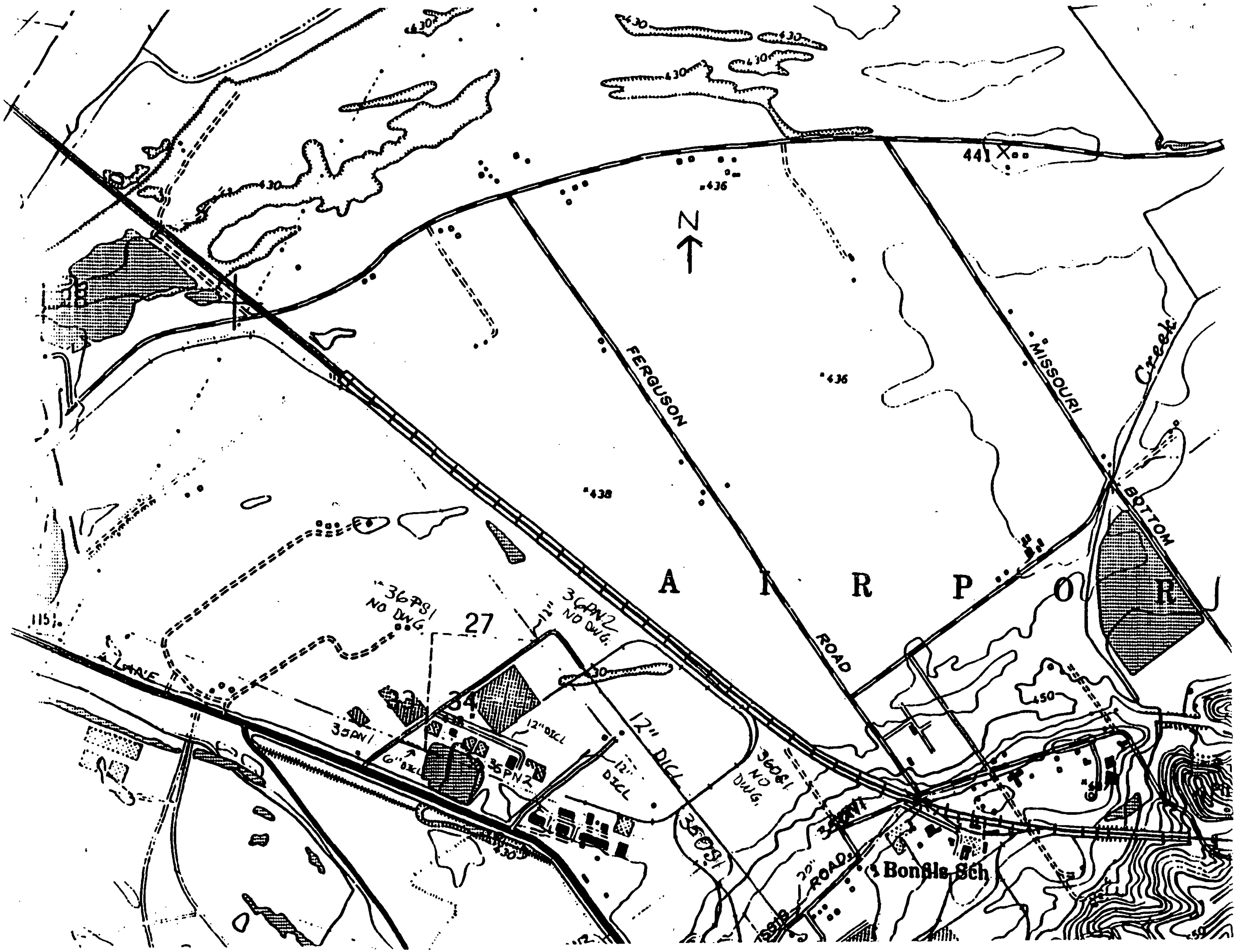
cc: Scott Schreiber w/attachments
Ron Poland w/attachments
Miles Stotts w/attachments



N
1" = 2000
15 14
22 23
21 22
MISSOURI
LEVEE
24
23
14
22
13
21
15
16
17
12
11
10
8
7
9
6
5
3
26
2
1
5900'
A I R P O R T
18
25
19
27
20
FERGUSON ROAD
MISSOURI BOTTOM
WASTE BOUNDARY
Pits
Bonfils
Bonfils Sch
Natural Bridge Junction
Mile 30
TWAIN

ATTACHMENT A

St. Louis Water Company
Information



N
FERGUSON
ROAD
MISSOURI
BOTTOM
ROAD
Creek
A I R P O R
Bonfils Sch
LANE
27
36PS1
NO DWG.
36PN2
NO DWG.
12"
35PN1
6" DICL
12" DICL
36PN2
12" DICL
12" DICL
36OS1
NO DWG.
35OS1
36PN1
20"
430
436
438
441
450

The water mains shown on the attached figure were found on maps belonging to the St. Louis County Water Company. Plat numbers are given on the figure. The area of interest can be found on maps of plats

34PN2
35ON1
35PN1
35PN2
35PS1

The areas to the northeast and northwest are plats

36PS1
36PN2
36OS1

St. Louis County Water Company maps are not available for these areas as water mains do not exist in this area.

ATTACHMENT B

Well Locations

Well Uses

1. Metal Shop - Not used as drinking water
2. Does not exist
3. Home
4. Bait Shop - Not used as drinking water
5. Home/Farm
6. Home/Farm
7. Home/Irrigation
8. Home
9. Home/Farm
10. Home/Farm
11. Shooting/Gun Club - Drinking water supply
12. Home
13. Home/Farm
14. Home/Farm
15. Irrigation
16. Irrigation
17. Irrigation
18. Bobs Auto Parts
19. Does not exist
20. Wilfred Hahn
21. House/Horse Ranch
22. Home/Farm
23. Home/Farm
24. Schroeder Sod Farms
25. Old Bridge Bait Shop
26. Home

ATTACHMENT C

NRC Report

The alluvial aquifer recharges from upland areas from three sources: seepage from loess and bedrock bordering the valley, channel underflow of upland streams entering the valley, and seepage losses from streams as they cross the floodplain. Of these sources, streams and their underflow represent the main source of upland recharge to the alluvial aquifer. Streams entering the floodplain raise the water table in a fan-shaped pattern radiating outward from their point of entrance to the plain. In areas where streams are not present, the water slopes downward from the hills, steeply at first and then gently to the level of the free water surface in the Missouri River channel. The situations described above do not take into account the effect of variations in permeability of the shallow soil layer. Aerial photography of the site indicates that a filled backchannel (oxbow lake) type of soil deposit is present along the southwest boundary of the landfill (USDA, 1953). This deposit is probably composed of fine-grained material to the depth of the former channel (6 to 10 m) (20 to 33 ft). This deposit may tend to hamper communication between shallow groundwater on opposite sides of the deposit.

Since no other recharge sources exist above the level of the floodplain, the only water available to leach the landfill debris is that resulting from rainfall infiltrating the landfill surface. Because the underlying alluvial aquifer is highly permeable, there will be little "mounding" of water beneath the landfill. Because the northern portion of the landfill has a level surface it is likely that at least half of the rainfall infiltrates the surface. The remaining rainfall is lost to evapotranspiration and (to a lesser degree) surface runoff. Due to the height of the berm, temporary impoundment of surface runoff is a common occurrence.

No public water supplies are drawn from the alluvial aquifer near the West Lake Landfill. It is believed that only one private well (Figure 2.9) in the vicinity of the landfill is used as a drinking water supply. This well is 2.2 km (1.4 miles) N 35°W of the former Butler-type Building location on the West Lake Landfill. In 1981, analysis showed water in this well to be fairly hard (natural origins) but otherwise of good quality (Long, 1981).

Water in the Missouri River alluvium is hard and usually contains a high concentration of iron and manganese (Miller, 1977). The amount of dissolved

ATTACHMENT D

HRS Scoring Worksheets

Scenario 1

Ground Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score			15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3	6	9	
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	16	40	
	Total Targets Score		22	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			25740	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	44.90		

FIGURE 2
GROUND WATER ROUTE WORK SHEET

Scenario 1

Surface Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	0	45	4.1
If observed release is given a value of 45, proceed to line 4. If observed release is given a value of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 3	1	2	3	
1-yr. 24-hr. Rainfall	0 1 2 3	1	2	3	
Distance to Nearest Surface Water	0 1 2 3	2	4	6	
Physical State	0 1 2 3	1	3	3	
	Total Route Characteristics Score		11	15	
3 Containment	0 1 2 3	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					4.5
Surface Water Use	0 1 2 3	3	6	9	
Distance to a Sensitive Environment	0 1 2 3	2	0	6	
Population Served/Distance to Water Intake Downstream	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
	Total Targets Score		6	55	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			5148	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{sw} =	8.00		

FIGURE 7
SURFACE WATER ROUTE WORK SHEET

Scenario 1

	s	s^2
Groundwater Route Score (S_{gw})	44.90	2016.01
Surface Water Route Score (S_{sw})	8.00	64.00
Air Route Score (S_a)	---	---
$S^2_{gw} + S^2_{sw} + S^2_a$		2080.01
$\sqrt{S^2_{gw} + S^2_{sw} + S^2_a}$		45.61
$\sqrt{S^2_{gw} + S^2_{sw} + S^2_a} / 1.73 = S_M =$		26.36

FIGURE 10
WORKSHEET FOR COMPUTING S_M

Scenario 2

Ground Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score			15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3	9	9	
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	12	40	
	Total Targets Score		21	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			24570	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} = 42.86			

FIGURE 2
GROUND WATER ROUTE WORK SHEET

Scenario 2

Surface Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	0	45	4.1
If observed release is given a value of 45, proceed to line 4. If observed release is given a value of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 3	1	2	3	
1-yr. 24-hr. Rainfall	0 1 2 3	1	2	3	
Distance to Nearest Surface Water	0 1 2 3	2	4	6	
Physical State	0 1 2 3	1	3	3	
	Total Route Characteristics Score		11	15	
3 Containment	0 1 2 3	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					4.5
Surface Water Use	0 1 2 3	3	6	9	
Distance to a Sensitive Environment	0 1 2 3	2	0	6	
Population Served/Distance to Water Intake Downstream	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
	Total Targets Score		6	55	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			5148	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{sw} = 8.00			

FIGURE 7
SURFACE WATER ROUTE WORK SHEET

Scenario 2

	s	s^2
Groundwater Route Score (S_{gw})	42.86	1836.98
Surface Water Route Score (S_{sw})	8.00	64.00
Air Route Score (S_a)	---	---
$S_{gw}^2 + S_{sw}^2 + S_a^2$		1900.98
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$		43.60
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2} / 1.73 = S_M =$		25.20

FIGURE 10
WORKSHEET FOR COMPUTING S_M

Scenario 3

Ground Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score			15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3	9	9	
Distance to Nearest Well/Population Served	0 4 6 8 10 / 12 16 18 20 / 24 30 32 35 40	1	8	40	
	Total Targets Score		17	49	
6 If line 1 is 45, multiply 1 x 4 x 5 / If line 1 is 0, multiply 2 x 3 x 4 x 5			19890	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	34.69		

FIGURE 2
GROUND WATER ROUTE WORK SHEET

Scenario 3

Ground Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multiplier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score			15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3	9	9	
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	8	40	
	Total Targets Score		17	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			19890	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	34.69		

FIGURE 2
GROUND WATER ROUTE WORK SHEET

Scenario 3

Surface Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	0	45	4.1
If observed release is given a value of 45, proceed to line 4. If observed release is given a value of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 3	1	2	3	
1-yr. 24-hr. Rainfall	0 1 2 3	1	2	3	
Distance to Nearest Surface Water	0 1 2 3	2	4	6	
Physical State	0 1 2 3	1	3	3	
	Total Route Characteristics Score		11	15	
3 Containment	0 1 2 3	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					4.5
Surface Water Use	0 1 2 3	3	6	9	
Distance to a Sensitive Environment	0 1 2 3	2	0	6	
Population Served/Distance to Water Intake Downstream	0 4 6 8 10 / 12 16 18 20 / 24 30 32 35 40	1	0	40	
	Total Targets Score		6	55	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			5148	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{sw} = 8.00			

FIGURE 7
SURFACE WATER ROUTE WORK SHEET

Scenario 3

	s	s^2
Groundwater Route Score (S_{gw})	34.69	1203.40
Surface Water Route Score (S_{sw})	8.00	64.00
Air Route Score (S_a)	---	---
$S_{gw}^2 + S_{sw}^2 + S_a^2$		1267.40
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$		35.60
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}\,/1.73 = S_M =$		20.58

FIGURE 10
WORKSHEET FOR COMPUTING S_M

20 pgs

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
1400 Independence Road
Mail Stop 200
Rolla, Missouri 65401

October 29, 1990

Miles Stotts
Laidlaw Waste System, Inc.
P. O. Box 5192
83rd and Indiana Streets
Kansas City, MO 64132

Dear Miles:

Enclosed is a copy of the draft study proposal we prepared for the West Lake Landfill approximately 5 years ago. As I discussed with you, this particular effort was never completed by our agency. This original proposal was prepared by Jeff Imes of our Missouri District office. I would like to still pursue this type effort and if you think of a way that we might be involved, let me know. As I mentioned to you, we can work with cities, states, counties, etc., on a 50/50 match program, but we cannot work with a private enterprise. In addition, we can directly work with other federal agencies. Thanks for the consideration.

Sincerely,

Daniel P. Bauer
District Chief

Enclosure

cc: Jan Neher, DNR, w/attachment

LAI 0295

EFFECTS OF CHEMICAL AND RADIOACTIVE WASTES FROM WEST LAKE LANDFILL ON THE MISSOURI RIVER ALLUVIAL AQUIFER, ST. LOUIS COUNTY, MISSOURI

INTRODUCTION

West Lake Landfill is located between St. Charles Rock Road and Old St. Charles Rock Road in Bridgeton, Mo., (northern St. Louis County). The site, approximately 200 acres, lies about 1 mile northwest of the junction of Interstate 270 and St. Charles Rock Road and about 1½ miles southeast of the Missouri River (fig. 1).

Mining of Mississippian-age limestone from beneath the thin alluvial deposits began at the site along the Missouri River bluff during the early 1940's. By the mid-1960's, the quarry had expanded to about 60 acres (Areas 1 and 2 in fig. 2). During this period of operation, about 84 acres adjacent to the western edge of the quarry site was covered with quarry waste material (Area 3 in fig. 2).

During the mid-1960's, before State regulatory authority over hazardous waste sites, the quarry began to be operated as a landfill. It was not until December 1973 that the landfill was brought into compliance with the Missouri Solid Waste regulation. During the interim, a variety of known and unknown chemical industrial wastes, in addition to the usual landfill materials, were buried at the landfill. Among the

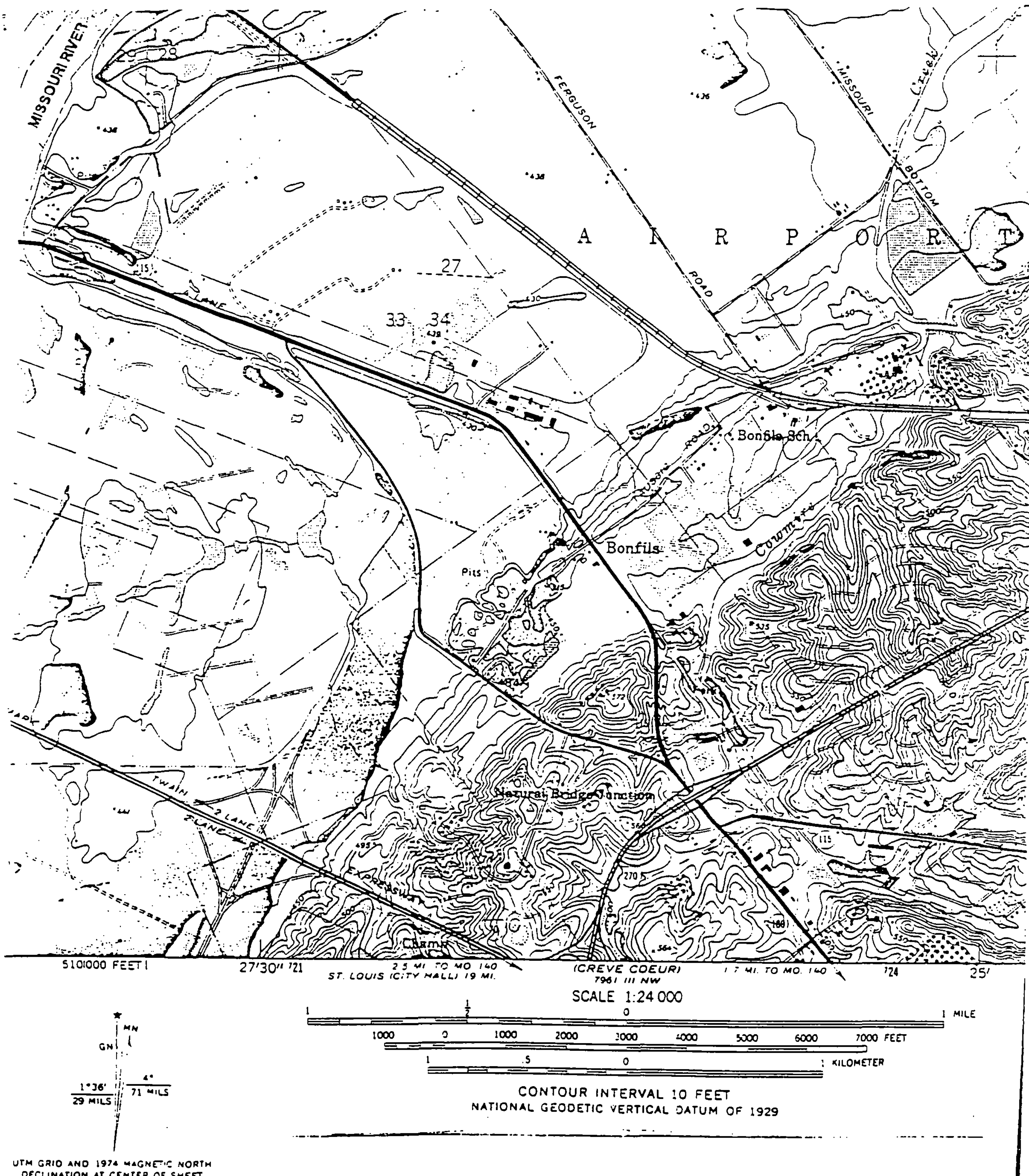


Figure 1.--Location of the West Lake Quarry and Landfill.

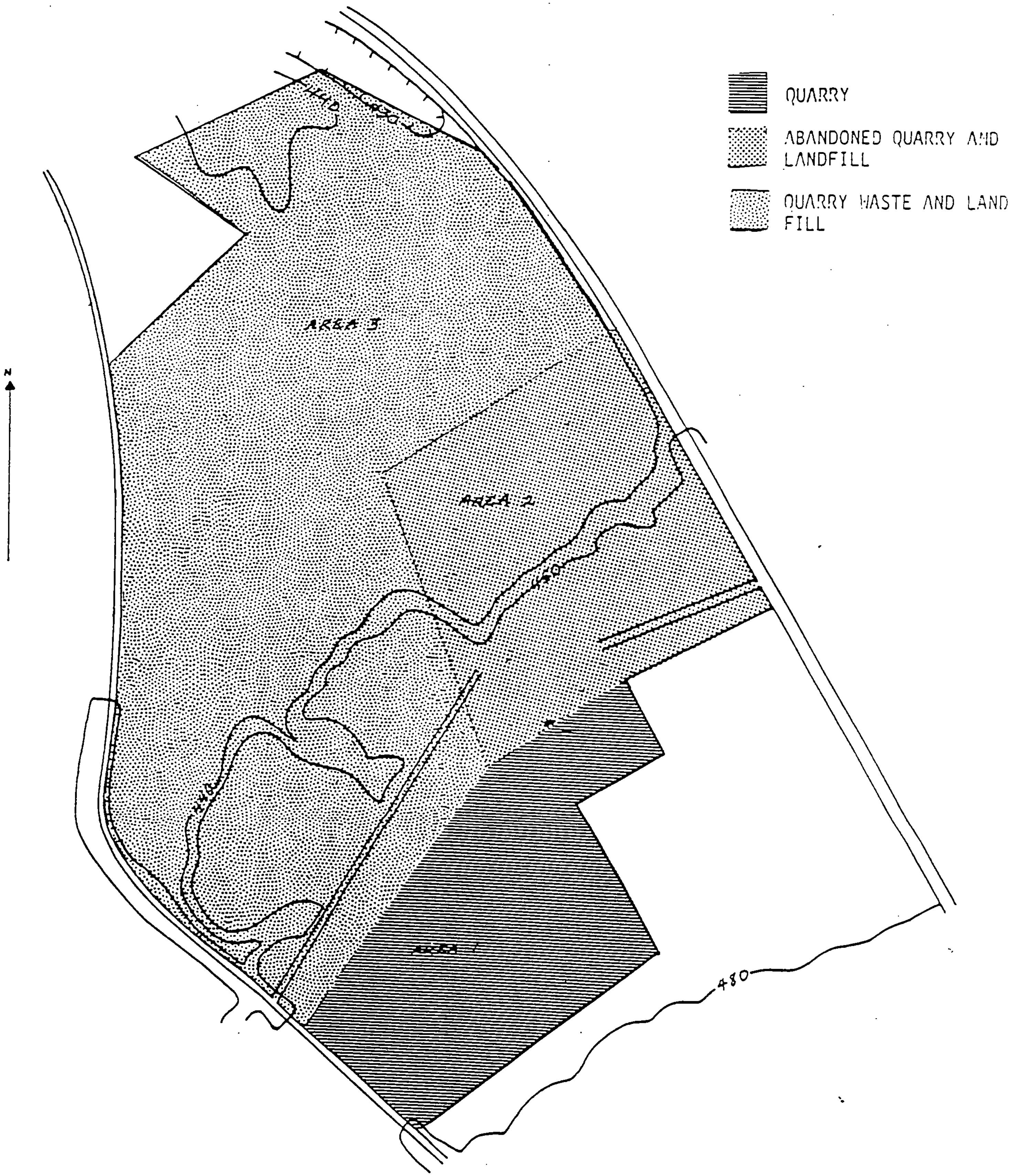


Figure 2.--Location of quarry, quarry waste, and landfill areas within West Lake Landfill.

chemical wastes that are known to have been deposited at the West Lake Landfill are:

Insecticides	Alcohol	Oils
Herbicides	Aromatics	Oily sludges
Heavy metals	Pigments	Wastewater sludges
Asbestos	Waste ink	Halogenated intermediates
Esters		

Approximately 4,000 tons of residue from the manufacture of herbicides and insecticides were deposited at the landfill site. Because no records were kept of the many different types of waste material being deposited at West Lake, it is improbable that a comprehensive list of chemical wastes can be compiled.

During early 1973 about 9,000 tons of barium sulfate slag residues and radiologically contaminated building rubble were removed from a uranium-processing plant at Latty Avenue. The material, containing about 7 tons of uranium oxide (U_3O_8), was mixed with 39,000 tons of soil and buried at West Lake. The major concentrations of radioactive deposits are in the northern one-half of the mid-1960's quarry location (area 2 in fig. 2) and adjacent to Old St. Charles Rock Road at the western edge of the landfill in the quarry waste area.

Since the early 1970's, the areal extent of the quarry has been reduced to about 25 acres in the southeastern part of the site and the landfill and quarry waste area have expanded to about 175 acres. A long-range development plan to utilize the site, as landfill operations cease, has been prepared. The initial proposal calls for filling and grading about 47 acres in the northeastern part of the landfill with demolition waste and developing an office-industrial park on the graded site. Approval for the demolition landfill and development plans has been withheld by the Missouri Department of Natural Resources pending a decision on the potential cleanup of radioactive wastes.

The area around West Lake Landfill has experienced a considerable increase in industrial and residential facilities since 1960. Completion of the Interstate 270 Bypass to the southeast and the Mark Twain Expressway to the west of the landfill site made the area more accessible to commuters and industrial transportation. Consequently, the population of the area has increased rapidly during the past 20 years. Southeast of the landfill, residential tracts have been developed adjacent to Interstate 270. Several industrial sites are located east of the landfill, across St. Charles Rock Road and a major industrial-residential park, Earth City, is being developed about 1 mile west of the quarry area. To the north there are industrial and commercial establishments along St. Charles Rock Road and farmland beyond. St. Charles, located 2 miles northwest of the landfill, across the Missouri River, is rapidly growing.

Geohydrology

West Lake Landfill is located at the boundary of the Missouri River alluvium. The southeastern one-third of the site, an active limestone quarry, lies on a small plateau about 20 feet above the alluvial flood plain at the base of a bluff overlooking the Missouri River. The quarry site presently occupies about 25 acres (Area 1 in fig. 2) and contains a body of water known as the Black Diamond Lake. Topographic maps show an elevation of 315 feet in the quarry at the north edge of Area 1. North of the present quarry site is a roughly square area of about 38 acres, the location of previous quarry activity (Area 2 in fig. 2). Most of Area 2 lies on the Missouri River alluvial flood plain. Alluvial overburden was removed to expose the limestone strata, which was quarried for about 15 years before the area became a landfill site. The remaining area (Area 3 in fig. 2) lies on the Missouri River alluvial flood plain. A geologic section traversing the alluvium about 1 mile north of the landfill depicts a large deposit of highly permeable sand and gravel (85 feet thick) at the base of the alluvium overlain by 15 to 35 feet of sand (fig. 3). Generally, alluvial clay deposits comprise the surface formations near the bluff at the southeastern edge of the alluvium. Soil conditions to the water table at the landfill are variable, ranging from clay and silty clay overlying sand in the south to sand in the north.

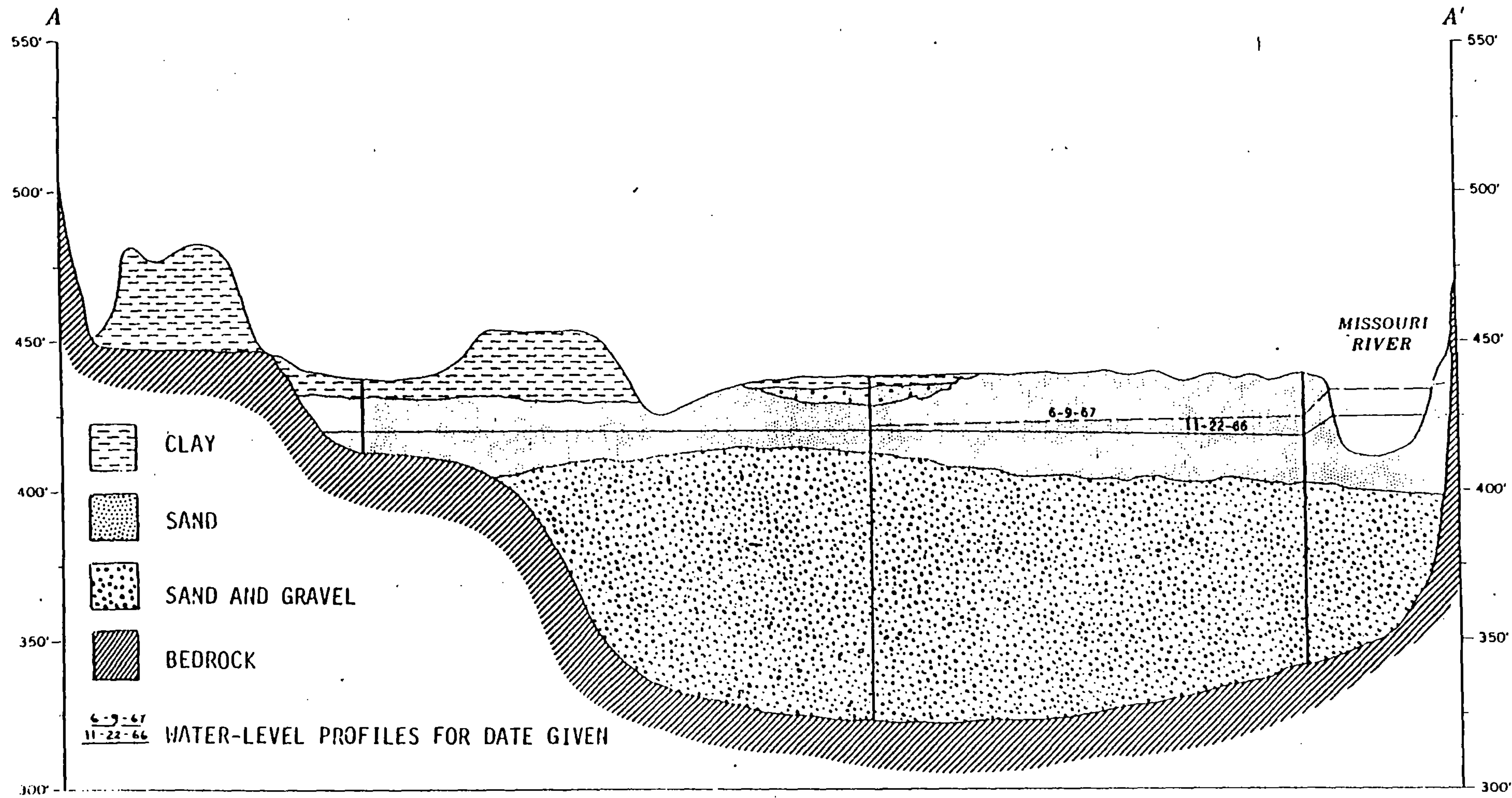


Figure 3.--Geologic section traversing the Missouri River alluvium about one mile north of West Lake Landfill. (Location of the section is shown in figure 4.)

The regional ground-water flow in the Mississippian limestone is northward, the water discharging into the Missouri River alluvium. On a local scale it is probable that the Mississippian aquifer is recharged by some leakage from the Pennsylvanian overburden. In the alluvium, ground-water flow generally is believed to be northward from the landfill site, then northeast. Emmett and Jeffery (1968[1]) show a gound-water valley in the alluvial plain south of the Missouri River (fig. 4), indicating ground water in the alluvium may travel from 4½ to 5 miles before it discharges into the Missouri River. The water table at the landfill is approximately 430 feet and appears to decrease to about 420 feet over a distance of about 1½ miles, resulting in a hydraulic gradient of about 7 feet per mile. During 1967 an aquifer test was made at the Weldon Spring Ordnance well field located about 18 miles upstream on the Missouri River alluvium. The alluvial aquifer transmissivity calculated from the aquifer-test data is 270,000 gallons per day per foot (average permeability 3,000 gallons per day per square foot).

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[1]Emmett, L. F., and Jeffery, H. G., 1968, Reconnaissance of the ground-water resources of the Missouri River alluvium between St. Charles and Jefferson City, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-315.

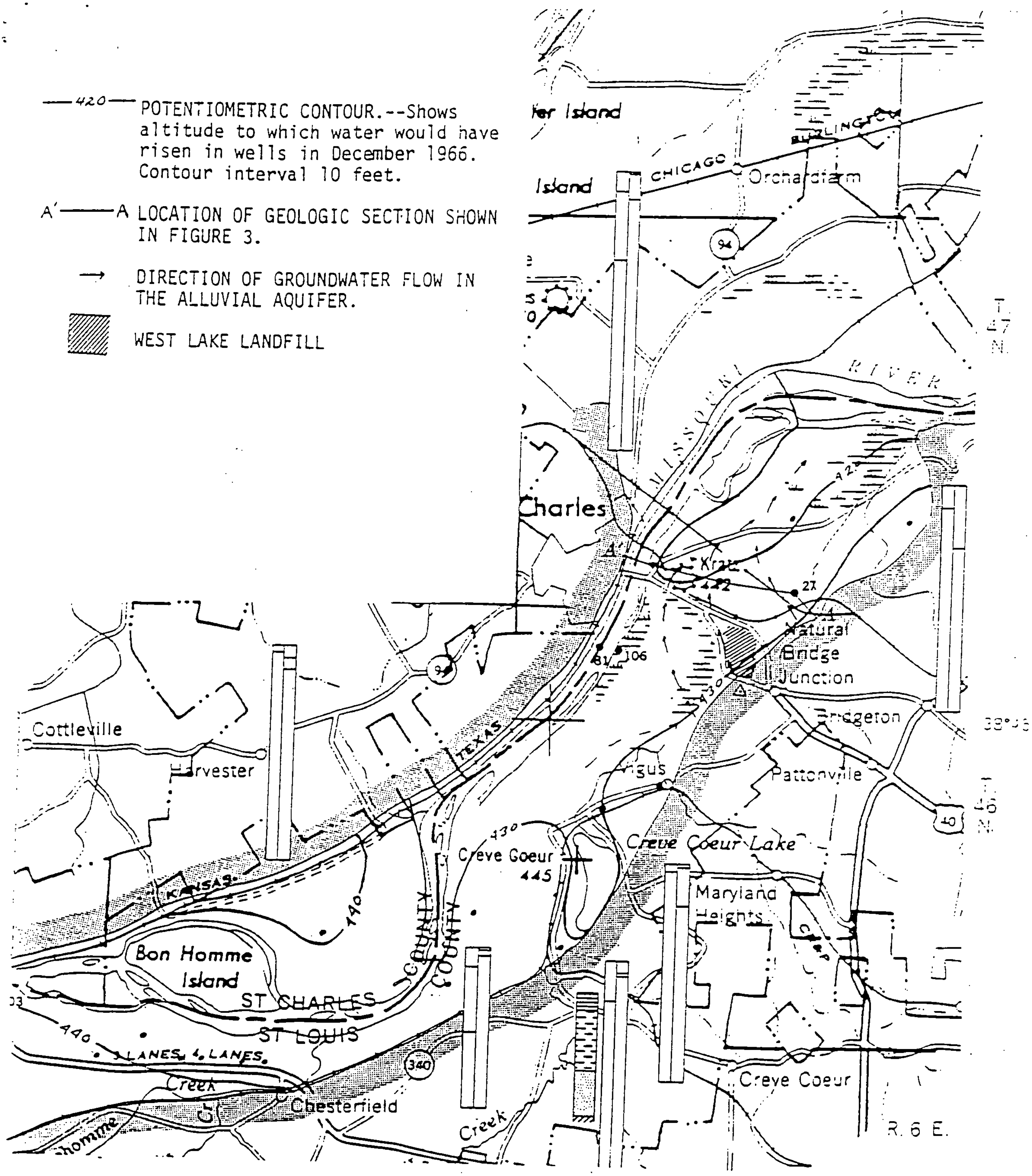

Figure 4.--Water table elevations in the Missouri River alluvial aquifer.
Arrows show probable direction of groundwater movement in the aquifer.

PROBLEM

West Lake Landfill potentially is a serious, long-term health risk for persons residing and working in the vicinity. Among the many known chemical and radiological contaminants buried at the landfill, which may adversely affect ground-water supplies in the alluvium, are heavy metals, asbestos, herbicides, and a suite of halogenated compounds. It is possible that oils, oily sludges and herbicides deposited at the site may contain dioxin impurities. The large quantity of barium sulfate slag, contaminated by radioactive uranium oxide (U_3O_8), is concentrated at two locations. One on the west edge of the landfill is adjacent to Old St. Charles Rock Road. The second is within an abandoned part of the limestone quarry (Area 2 in fig. 2). It is likely that this area of the quarry is hydraulically connected to the basal sand and gravel deposits of the alluvial flood plain. The nature of many of the chemical industrial wastes at the site are unknown because no records of the type of chemicals hauled into the landfill were kept by its owners.

Precipitation falling on the landfill does not run off as overland flow but soaks into the interior of the landfill. Witnesses have stated that the active parts of the landfill were often under water. The site apparently is permeable enough to allow the water to infiltrate, presumably continuing its flow into the alluvium. The dike on the north and west of the landfill is in poor condition and may allow leachate to leak from the landfill.

The average velocity of fluid flow through the alluvium can be estimated using the aquifer transmissivity calculated from the aquifer test at Weldon Spring Ordnance well field. Assuming a porosity of 20 percent, the flow rate is approximately 900 feet per year. This does not imply that chemical constituents will move at this rate but is a rough estimate of the hydraulic properties of the alluvium. At this rate of movement, and assuming an active landfill history of 20 years, contaminated ground water could have moved a maximum of about 3½ miles from the site since its initial operation as a landfill. This does not take into account the confining nature of near-surface clay deposits, which may underlay part of the landfill, but would be appropriate for parts of the landfill that are in direct or near-direct contact with alluvial sand, such as is possible in the abandoned quarry.

OBJECTIVES

The focus of this study is to determine the spatial distribution of chemical and radioactive contaminants in and adjacent to the West Lake Landfill and evaluate the probable rate and direction of leachate plume migration from the landfill site. The extent and severity of contamination in the alluvial aquifer and the potential for contamination of ground-water supplies and the Missouri River downgradient from the landfill will be evaluated.

STUDY AREA

The study area includes the West Lake Landfill site, the Missouri River bluff at the south edge of the quarry, and the Missouri River alluvium from about 1 mile upstream from the landfill northeast to the convergence of the Missouri River and the bluffs southeast of the alluvium, a distance of about 2.3 miles. The extension well beyond the boundaries of the landfill is necessary to adequately determine the regional ground-water flow through and around the landfill site.

PREVIOUS WORK

A brief engineering geologic report was filed on the West Lake Landfill after the site came under the Missouri Solid Waste regulation. The report recommends that no excavations be made below the original flood-plain elevation (estimated at 440 feet) to keep the landfill above the water table. Test borings in the quarry spoil pile indicated a clay and silt composition, but the nature of the alluvial flood-plain surficial soil was not noted. Mention is made of a discontinuous dark gray clay at approximately 20 feet below land surface.

During 1980 an increasing interest in the landfill site and its potentially hazardous nature lead the Missouri Department of Natural Resources to initiate a study to determine the geologic history and hydrology of the landsite and identify chemical and radioactive pollutants that may have leached into the ground water. The two site surveys conducted during late 1980 failed to address the question of the geologic history of the landfill and adjacent flood plain except to provide a sketch of the expansion of the quarry since its beginning. Only 5 of 11 planned wells were completed at the landfill site. Three are located immediately outside the west perimeter of the landfill in the direction hypothesized as upgradient and two are located inside the north boundary of the landfill. The wells were drilled only to a depth about 1 meter below water table. Water-level measurements made in these wells do not adequately describe the hydrology of the landfill or its relation to the surrounding alluvial plain. No attempt was made to measure changes in water levels with depth to determine if water leaks vertically downward in the alluvium. The study did note movement of water from the landfill into Black Diamond Lake at the southern boundary of the quarry. Several chemical samples were obtained from the five newly drilled wells, two existing monitor wells at the landfill, three private wells, and two surface locations. The private wells are located beyond the boundaries of the landfill along St. Charles Rock Road, between the landfill and the Missouri River, but apparently are not downgradient from the buried waste (fig. 4). Chloride, sodium, lead, and manganese concentrations are mentioned as being particularly large in these samples, but comparison with chemical analyses from other alluvial wells show the manganese content to be within the same range of values. Sodium and chloride concentrations are unusually large only in samples taken from the landfill.

During December 1981, water-level measurements and water-quality samples were obtained by Reitz and Jens, Inc. (consulting engineers) at eight monitoring wells within the boundaries of the landfill. None of these samples and only seven of the aforementioned samples were tested for barium, although large quantities of barium sulfate slag contaminated with radioactive uranium oxide (U_3O_8) were deposited at the site.

A detailed radiological survey of West Lake Landfill was completed during 1982 by Radiation Management Corporation for the U.S. Nuclear Regulatory Commission (Booth and others, 1982[2]). The study identified gamma-ray exposure rates, surface and subsurface radionuclide concentrations, and several other measures of radioactive contamination. An aerial survey of the landfill revealed that gamma-ray intensities from the buried radioactive material reaches 84-116 μR/hr (adjusted to the 1-meter level and including 3.7 μR/hr background cosmic radiation at the two

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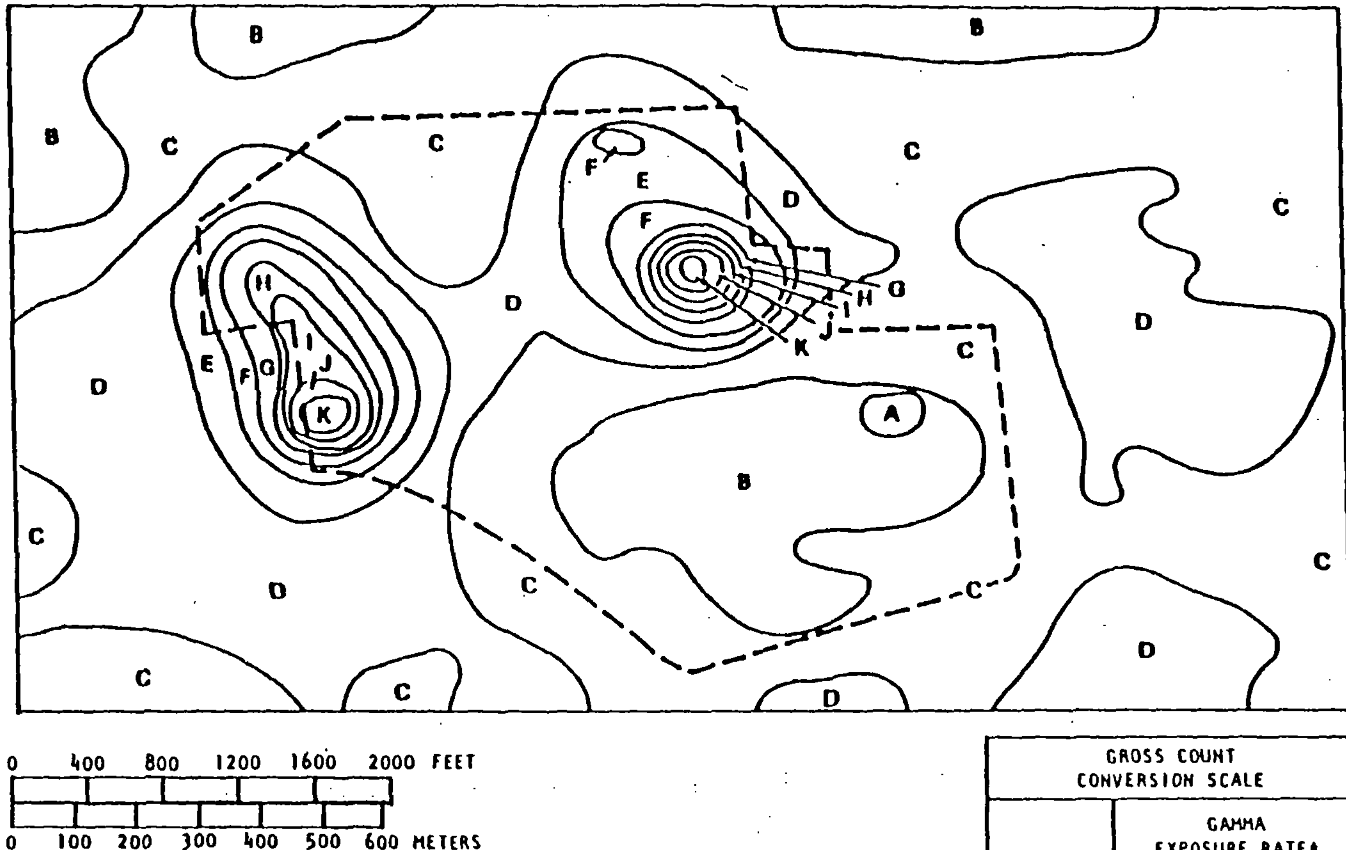
[2]Booth, L. F, and others, 1982, Radiological survey of the West Lake Landfill St. Louis County, Missouri: Northbrook, Ill, Radiation Management Corporation, NUREG/CR-27722, 132 p.

sites of major concentration of the wastes (fig. 5). In addition to the investigation of radiological contamination, the study also includes a chemical analysis of six samples for priority pollutants. The analyses show a significant presence of organic solvents. Among those found in large concentrations are chlorophenol (1,415 micrograms per liter [ug/L]), chlorodane (940 ug/L) trichloroethylene (725 ug/L) ethylbenzene (438 ug/L), phenol (159 ug/L), and trichlorofluoromethane (148 ug/L.

APPROACH

The hydrological and chemical assessment of the West Lake Landfill will begin with a compilation and thorough analysis of existing geologic, hydrologic, and chemical data obtained from the landfill and the Missouri River, and from the alluvial flood plain between the landfill and the Missouri River, and from the uplands south of the landfill. This information will be used to verify the present or formulate a new concept of the ground-water flow system in and around West Lake Landfill, including vertical flow in the alluvium.

A network of wells will be drilled into the alluvium and landfill to provide information that will define the geology of the material on which the landfill rests (especially the areal distribution and thickness of confining clay deposits), refine the conceptual ground-water flow pattern, and provide samples for chemical analysis. Previously drilled wells will be used wherever it is practical. The



GROSS COUNT CONVERSION SCALE	
LETTER LABEL	GAMMA EXPOSURE RATE* 1 m LEVEL (μR/hr)
A	- 6
B	6 - 8
C	8 - 10
D	10 - 13
E	13 - 17
F	17 - 24
G	24 - 33
H	33 - 45
I	45 - 62
J	62 - 84
K	84 - 116

*AVERAGED OVER DETECTABLE FIELD-OF-VIEW AT 60 m ALTITUDE AND EXTRAPOLATED TO THE 1 m LEVEL INCLUDES 3.7 μR/hr COSMIC RADIATION.

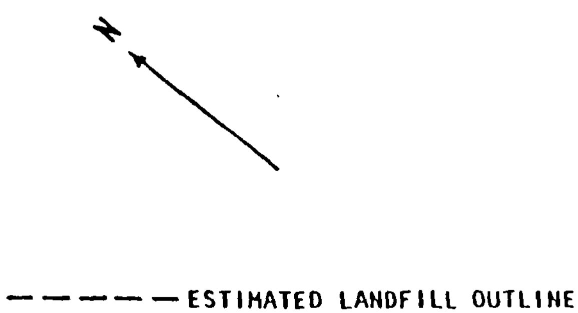


Figure 5.--Gamma ray intensities from radioactive debris buried at West Lake Landfill.

location of new wells will be determined pending the results of the initial site survey and analysis of existing data. It is anticipated that wells will be placed both upgradient and downgradient from the landfill. A lithologic log of each well will be prepared. Water-level measurements and samples for chemical analysis will be made immediately after drilling below the water table and after drilling to bedrock. If a thick clay layer is penetrated, an attempt will be made to case the well above the confining layer and make additional water-level measurements and take water samples from the deeper alluvial deposits.

The hydrologic characteristics (hydraulic conductivity and specific yield) of the alluvium near West Lake Landfill will be determined by aquifer tests. A multiple-well aquifer test in the alluvium, downgradient from the landfill site, will provide information necessary to evaluate the rate of flow of water away from the landfill. A second test near the southern edge of the landfill will be particularly valuable in determining the rate of movement of water and leachates from the old quarry site (Area 2 in fig. 2) into the alluvium. A multiple-well test with one well penetrating the limestone beneath the southern edge of the landfill and a second well placed in the alluvium to the north would provide information on the hydraulic connection between the limestone bedrock and alluvial flood plain. The feasibility of the second well test will be investigated more thoroughly using known geologic data. It may be difficult to locate wells properly in this area to obtain a drawdown in the observation well within a reasonable test period. A long-term test of the hydraulic connection may be made by injecting dye at the base of the old quarry and sampling for it in the alluvium. It is not certain that the dye would be detected at a monitor well.

A digital model of the ground-water flow system in the landfill and alluvium north and northeast of the landfill will be designed and calibrated to on-site observations. A decision on the type of model that will be most appropriate to the situation will be made as geologic and hydrologic information is acquired and a conceptual ground-water flow pattern is developed. The model may be a two-dimensional, three-dimensional, or vertical-section model. The model will be used to assess the applicability of field-measured hydraulic conductivity and specific yield values to regional flow through the aquifer and to estimate the probable past and future movement of leachate from the landfill into the alluvium.

Chemical analyses of water samples previously taken from the landfill site and results of the priority pollutant analysis conducted by Radiation Management Corporation will be studied to determine potential tracer elements that may be used to map the movement of leachate plumes. Water samples from new wells and existing monitor wells will be analyzed for the tracer elements and other contaminants to determine the extent of leachate migration and the types of chemical contaminates moving in the ground water. Water samples also will be taken from wells upgradient from the landfill to determine background chemical characteristics of ground water moving into the landfill. Information about the spatial distribution of hazardous chemical and radioactive pollutants and the movement of ground water in the alluvial aquifer will be studied to evaluate the present and future threat to drinking-water supplies in the vicinity of the landfill. An investigation of the feasibility of using electromagnetic methods to locate the boundaries of leachate plumes in the alluvial aquifer will be undertaken as part of this study.

REPORT PLANS

An interpretive report describing the hydrologic system in the study area will be prepared and published as a U.S. Geological Survey Water-Supply Paper.

1 pg

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

September 13, 1990

William E. Whitaker
President
Rock Road Industries, Inc.
13570 St. Charles Rock Rd.
Bridgeton, MO 63044

Dear Mr. Whitaker:

This letter is notification that within the U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, responsibility for project management of the matter of the licensable-material contamination in the West Lake Landfill, Bridgeton, Missouri, Docket No. 40-8801, has been transferred from the Fuel Cycle Safety Branch, Division of Industrial and Medical Nuclear Safety, to the Regulatory Branch, Division of Low Level Waste Management and Decommissioning. In the future, correspondence may be addressed to John H. Austin, Chief, Regulatory Branch.

Sincerely,

Charles J. Haughney

Charles J. Haughney, Chief
Fuel Cycle Safety Branch
Division of Industrial and
Medical Nuclear Safety
Office of Nuclear Material Safety
and Safeguards

cc: Miles Stotts, Assistant Regional Engineer
Laidlaw Waste Systems, Inc.
2430 South Arlington Heights Road, Suite 230
Arlington Heights, Illinois 60005

William C. Ford, Director
Division of Environmental Quality
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, Missouri 65102

LAI 0296

2pg

JOHN ASHCROFT
Governor

FREDERICK A. BRUNNER
Director

STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES

Division of Energy
Division of Environmental Quality
Division of Geology and Land Survey
Division of Management Services
Division of Parks, Recreation and Historic Preservation

OFFICE OF THE DIRECTOR
P.O. Box 176
Jefferson City, Missouri 65102
Telephone 314-751-4422

CERTIFIED MAIL - P5N339829

September 3, ~~1987~~

RECEIVED
SEP 30 1987
WASTE MANAGEMENT PROGRAM

Mr. Daniel T. O'Leary
County Government Center
7900 Forsyth Avenue
Clayton, MO 63105

Dear Mr. O'Leary:

RE: Registry of Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites in Missouri - Modification of Legal Description

The Missouri Hazardous Waste Management Law directs the Department of Natural Resources to maintain a registry of confirmed abandoned or uncontrolled hazardous waste disposal sites in the state (Section 260.440, RSMo 1986). That law further provides that when the Director places a site on the Registry, he shall record with the County Recorder of Deeds the period during which the site was used as a hazardous waste disposal area (Section 260.470, RSMo 1986). The County Recorder of Deeds is directed to record this information so that any purchaser will be given notice that the site has been placed on the Registry. Id.

This particular site has already been added to the Registry and a "Notice" recorded. The area of the site has been reduced and a survey of that area performed. We are now modifying the legal description contained in the earlier "Notice" recorded March 16, 1987, Book 8083, 975. Please record the enclosed "Notice" concerning the modification of a previously recorded "Notice" in St. Louis County. Please note that no filing fee is enclosed because there is no statutory authorization to require the Director of the Department of Natural Resources to pay a fee for filing this notice. See Carpenter v. King, 679 S.W.2d 866 (Mo. banc 1984).

LAI 0297

Please advise the Missouri Department of Natural Resources, Waste Management Program, P.O. Box 176, Jefferson City, Missouri 65102 of the date the recording was made. If you have any questions or need further clarification, please contact me.

Sincerely,

DIVISION OF ENVIRONMENTAL QUALITY

Frederick A. Brunner, Ph.D., P.E.
Director

FAB:jbk

Enclosures

JOHN ASHCROFT
Governor

FREDERICK A. BRUNNER
Director

1pg

Division of Energy
Division of Environmental Quality
Division of Geology and Land Survey
Division of Management Services
Division of Parks, Recreation,
and Historic Preservation

STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF ENVIRONMENTAL QUALITY
P.O. Box 176
Jefferson City, MO 65102

CERTIFIED MAIL P062020300

August 30, 1988

Mr. William McCullough
13570 St. Charles Rock Road
Bridgeton, MO 63042

Dear Mr. McCullough:

RE: Westlake Landfill, Inc. Registry Site

We have learned that controlling interest of portions of the Westlake Landfill property have been acquired by Laidlaw Waste Systems. As you know, two parcels of property are listed on Missouri's Registry of Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites are believed to be owned by Westlake Landfill, Inc. Attached are legal descriptions of those registry sites--the radioactive waste sites.

It was also reported that a subsidiary corporation has been established and ownership of the registry sites was passed to it prior to the transaction with Laidlaw Waste Systems. Who or what entity now owns the registry sites as described in the attached legal descriptions? Please substantiate your response.

If you have questions, please do not hesitate to contact me at (314) 751-2919.

Sincerely,

DIVISION OF ENVIRONMENTAL QUALITY

Jim Belcher

Jim Belcher, Chief
Planning and Pre-Remedial Unit
Superfund Section
Waste Management Program

JB:ls

CC: Mr. Richard A. Volonino

LAI 0298